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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LUNAR SAMPLE ANALYSIS PROGRAM

A SUMMARY OF PHASE ANALYSIS ON APOLLO XIV SAMPLES

by

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October 1, 1971

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A SUMMARY OF PHASE ANALYSIS ON APOLLO XIV SAMPLES

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and

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ABSTRACT

The large number of breccias returned from the Fra Mauro formation show that impact events are an important rock forming mechanism on the moon. Larger rocks as well as micro breccias bear structural resemblance to brecciated chondrites and terrestrial impactites. Many show evidence of repetitious events of break-up and accumulation welding. The surface of the regolith has become thoroughly mixed by this process. Most components however appear locally derived from basalts rich in feldspar and Kreep components, similar to rocks such as 14310.

DESCRIPTORS

General Descriptors	Specific Descriptors	
Electron Microprobe	Olivine	Spinel
Breccias	Pyroxene	Metal
Chondrules	Plagioclase	Sulfide
Glasses	Feldspar	Ilmenite
Impact	Rare Earth	Phospate
Regolith	Baddeleyite	Whitlockite

A SUMMARY OF PHASE ANALYSIS ON APOLLO XIV SAMPLES

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Introduction: A large number of glasses and minerals in soil have been analyzed with the electron microprobe. Chemical compositions are given in tables in the appendix. A number of plots accentuate certain features and some comparisons are made with glasses from Apollo 11 and 12 samples. Many of the glasses are enriched in feldspar and Kreep components.

One of the more interesting breccias is rock 14318, which not only bears a structural resemblance to ordinary chondritic meteorites, but also contains a fair number of well developed chondrules. Rock 14321 is a different type of breccia and is also described.

SOIL: The -1mm fractions of six soil samples (14148, 14156, 14149 - surface, middle and bottom trench samples, 14163 - bulk sample near L.M. - and 14259, 14260 comprehensive samples) have been analyzed with the electron microprobe. Various constituents of glasses and minerals are reported in the Appendix. Although a complete summary of the data is beyond the scope of this report, certain trends are accentuated in Figures 1-3.

Norm glass compositions of Apollo 14 soils (Fig. 1) indicate enrichment in silica, feldspar components and low calcium pyroxene with respect to glasses from previous Apollo samples. A significant decrease in ilmenite and olivine can also be observed.

In Figure 2 (A-D) individual glasses are arranged in triangular plots, the quartz and feldspar forming one coordinate, anorthite another, while the mafic minerals and ilmenite comprise the third coordinate. In addition titanium levels are indicated by symbol type. Here various groups of glasses become apparent. Apollo 11 glasses (Fig. 2A) all are related in composition to the Mare Tranquillitatis basalt, low in feldspar and not too silica rich. Although a large portion of the Apollo 12 glasses (Fig. 2B) still appears to be Mare basalt derived, a smaller cluster shows definite enrichment in

feldspar components. This same cluster also was found to be enriched in KREEP (1) as was demonstrated by ion probe analyses of these glasses (2). In the Apollo 14 glasses the quartz feldspar component is much more abundant (Fig. 2 C-D). Spot checks with the microprobe show some of these glasses also to contain up to several tenths of one percent of barium or phosphorus, components associated with KREEP in Apollo 12 glasses. Of the few crystalline rocks returned from Fra Mauro site, rock 14310 is quite enriched in KREEP components (3). Basalts similar to this seem to be the source material for many of these glasses.

Compositions of soil pyroxene, plagioclase and olivine can be found in Tables 2, 4, 6, 8, 9, 11, 13. Pyroxenes are plotted in Figure 3 A-B. Hypersthene and pigeonite predominate. Plagioclase is very abundant and ranges mostly between AN80 - AN90. Olivine centers around Fa 40.

Other minerals analyzed include K-feldspar (Table 8, 9), baddeleyite (Table 8, 9), phosphate, whitlockite (Table 9) and ilmenite and metal (Table 8, 11). A chromespinel (Table 8), which has not been observed in previous lunar samples, is fairly abundant.

BRECCIAS: Two breccias were analyzed.

Rock 14318 is a highly complex breccia, consisting of angular clastic fragments, set in a dark matrix. It has well developed chondrules, consisting of plagioclase grains and glass. The glass is very inhomogenous, indicating rapid cooling. This breccia could be called a lunar chondrite, sintered and strongly welded. The analyzed plagioclase in the chondrules has a very uniform composition (AN 87-90, Table 14) in contrast to the plagioclase in the rest of the rock, which ranges between AN 40-95 (Table 16). The glass in this rock exist only in the host and chondrules, not in the recrystallized fragments. A bargraph (Fig. 4) shows the average normcomposition of this glass. The anorthite component is decidedly higher then for the average soil glasses (Fig. 1). Norms of the individual glasses have been plotted in Figure 5, and further accentuate the difference with the soil glasses, including a much smaller degree of mixing. Only two types of pyroxenes were observed, again showing much less mixing then has occurred in the regolith. The components of this breccia however, highly feldspatic and Kreep rich, still relate to local rock types. It is therefore likely that this breccia was formed in the Fra Mauro formation, but in a single event, which penetrated deep into the regolith, possibly into the underlaying bedrock.

The second breccia analyzed is rock 14321 (Table 17 and 18). Again it is a highly complex rock, consisting of fine to coarse grained basaltic fragments (some recrystallized), anorthosites and zoned

orthopyroxenes (Fig. 7). Highland components include K-feldspars, some barium-rich, and quartz feldspar intergrowth. The absence of fresh glass as well as the zoning in some of the pyroxenes could indicate that this rock was lithified below the surface and brought up during a later event. The multitude of cracks traversing the rock and its various components probably were brought on during this event.

Figure Captions

Fig. 1 Normative glass compositions of various Apollo 14 soils (14148, 14149, 14156, 14163, 14259 and 14260) are compared with glasses from Apollo 11 and 12 soils.

Fig. 2 Glass compositions of Apollo 11, 12 and 14 soils in triangular plots. The three coordinates represent respectively the quartz-feldspar component, the anorthite component and the olivine-pyroxene-ilmenite component. In addition ilmenite levels are indicated by symbol type.

A Apollo 11 soils.

B Apollo 12 soils.

C Apollo 14 trench soil samples, station G.

D Apollo 14 soils from bulk sample, near LM, (14163) and Comp. Spl. (14259 and 14260).

Fig. 3 Normative pyroxene plots in Apollo 14 soils.

A Pyroxenes from surface, middle and bottom trench soils.

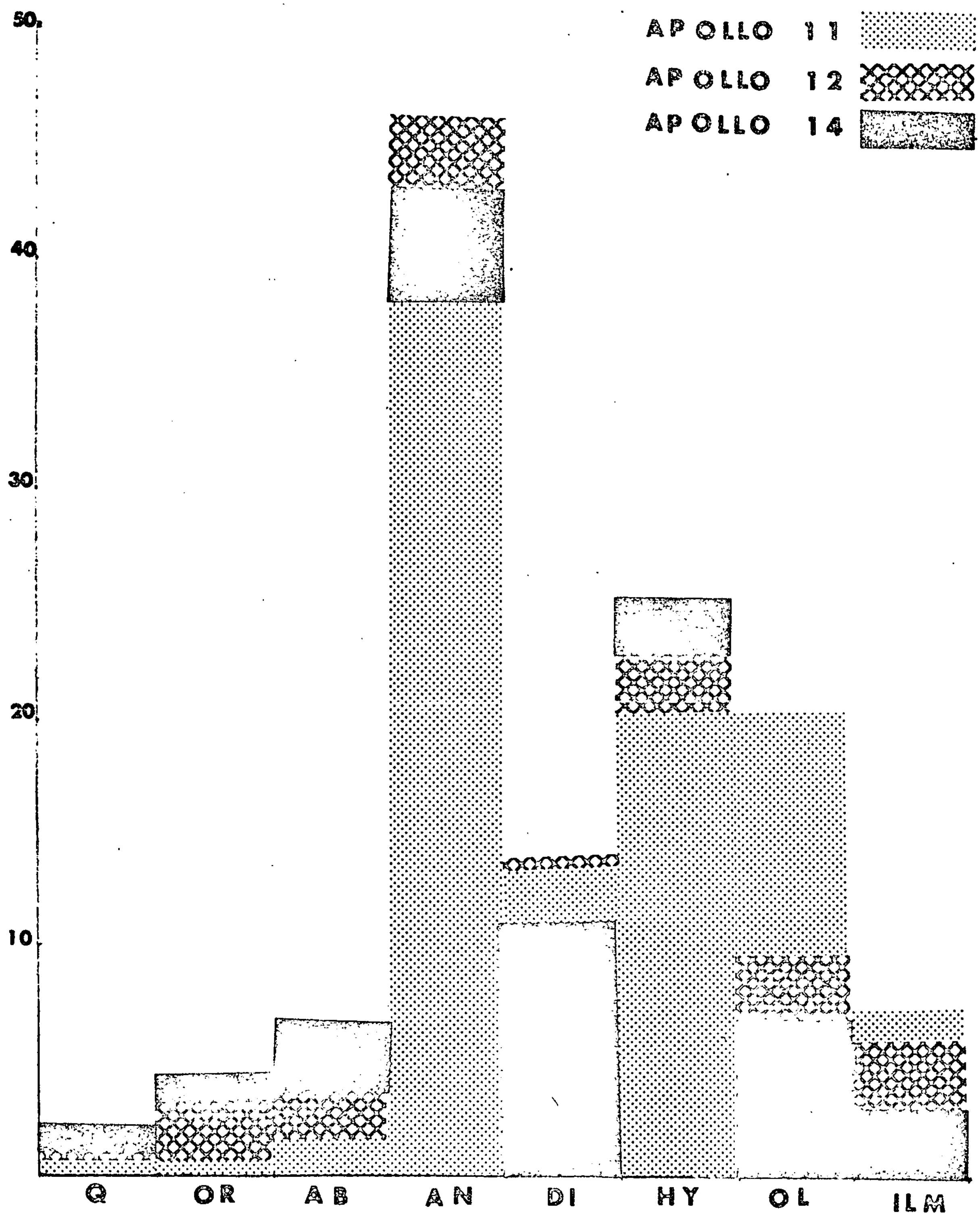
B Pyroxenes from soil samples 14163, 14259 and 14260.

Fig. 4 Bargraph compares normative composition of matrix-glass in breccia 14318 and Apollo 11 and 12 soil glasses. Notable differences with Apollo 14 soil glasses (Fig. 1) are high anorthite and low olivine contents in this breccia glass.

Fig. 5 Normalized glass compositions in 14318 reveal three distinct clusters. One cluster of glasses is rich in anorthite and low in ilmenite, another one relatively high in ilmenite, mafic components and feldspar, with the third cluster falling between these two.

Fig. 6 A normative plot of pyroxenes in breccia 14318. Again there is distinct clustering.

Fig. 7 Pyroxenes in breccia 14321. Zoning is indicated by connecting lines. M = Margin; C = Center.



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30
20
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APOLLO 12
APOLLO 14
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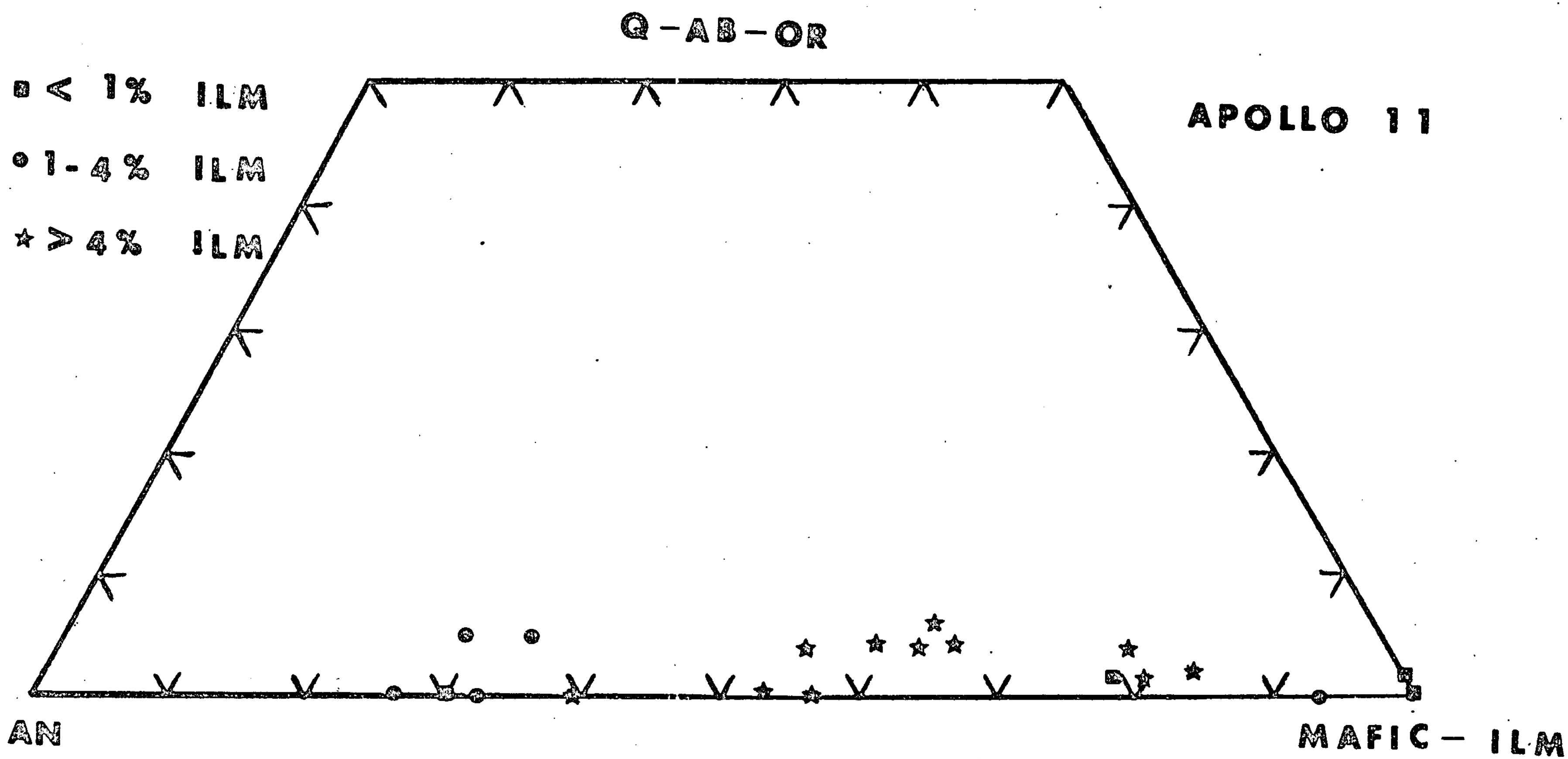
Figure 1

Figure 2A



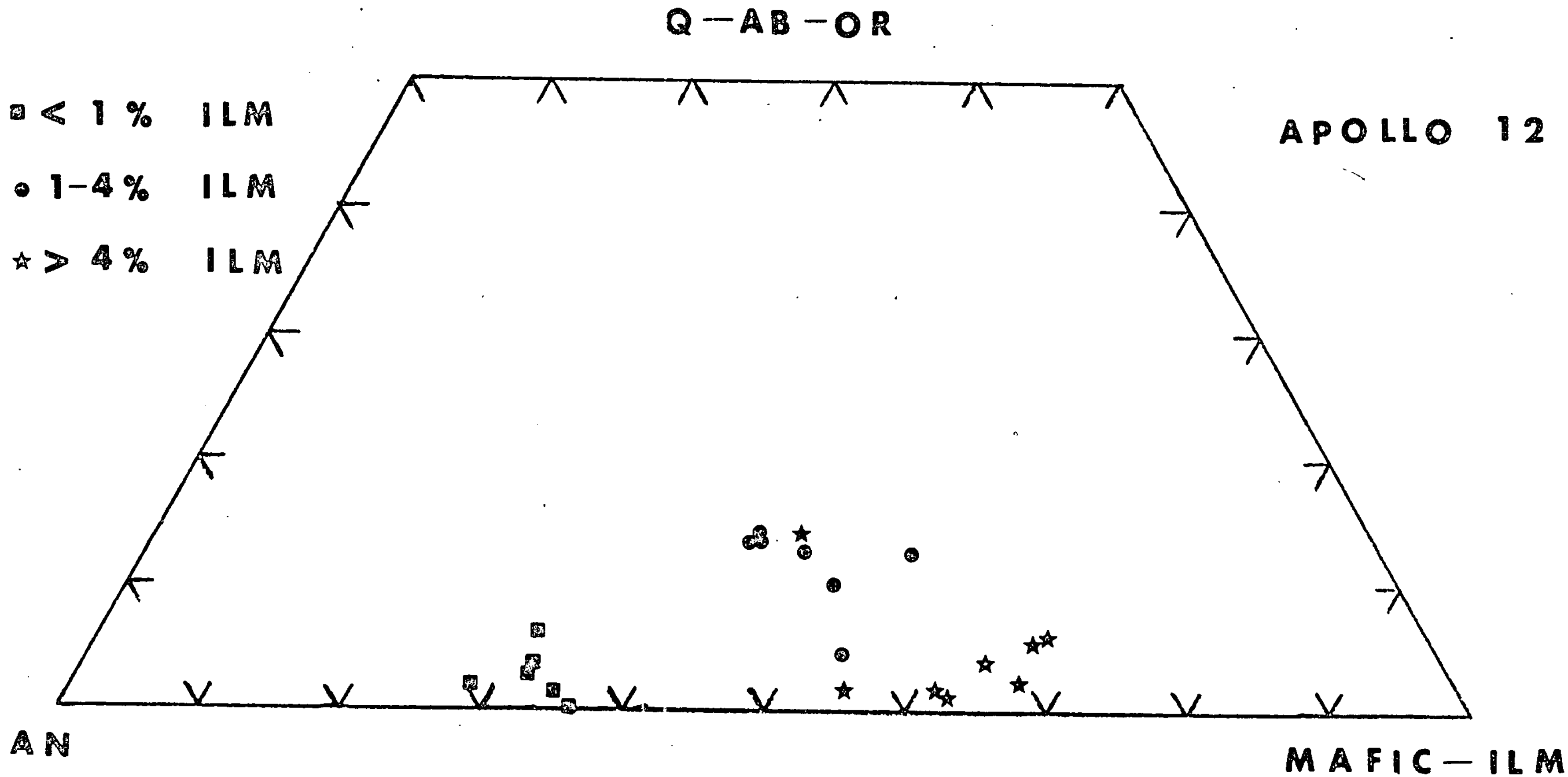


Figure 2B

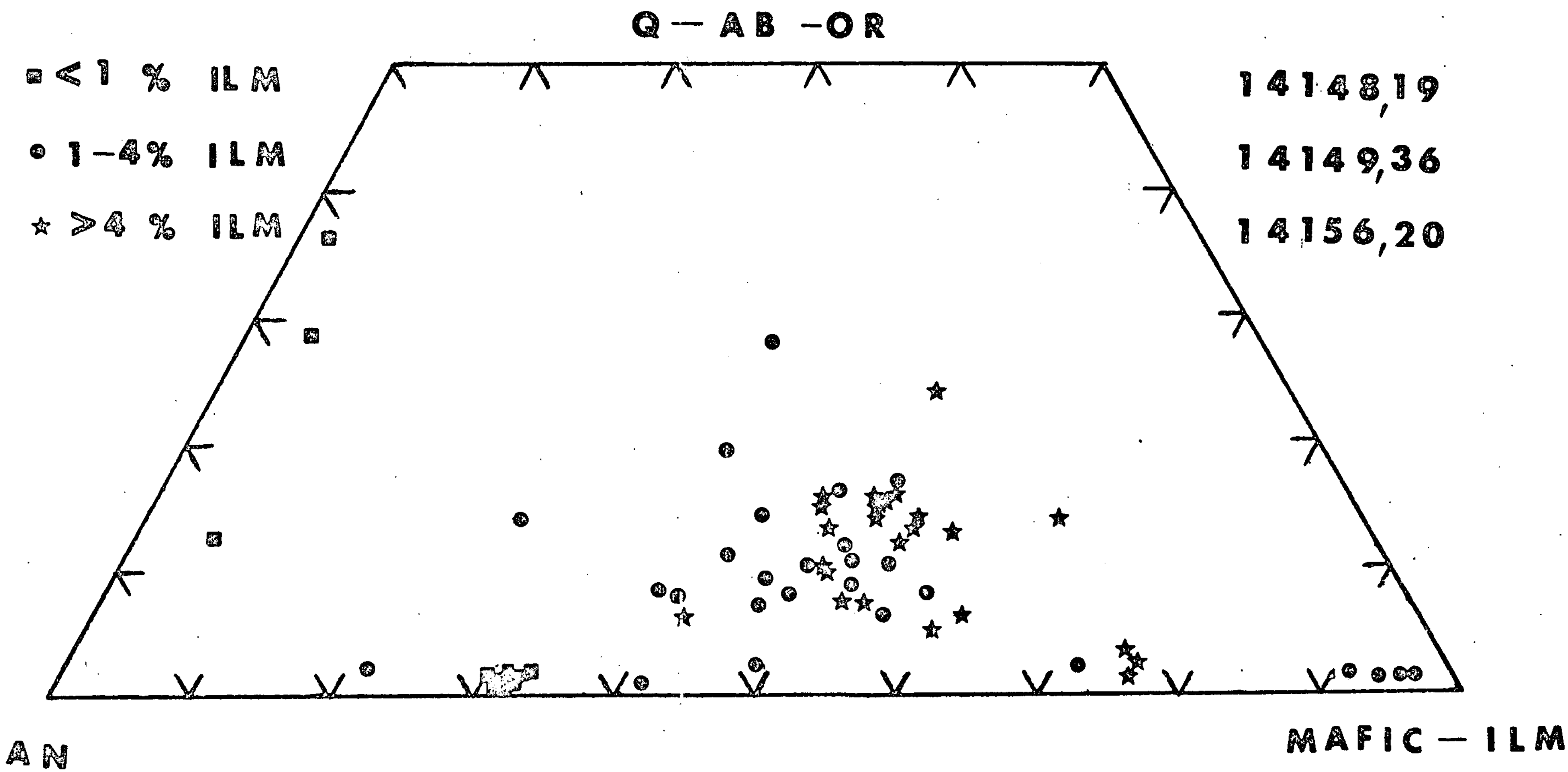


Figure 2C

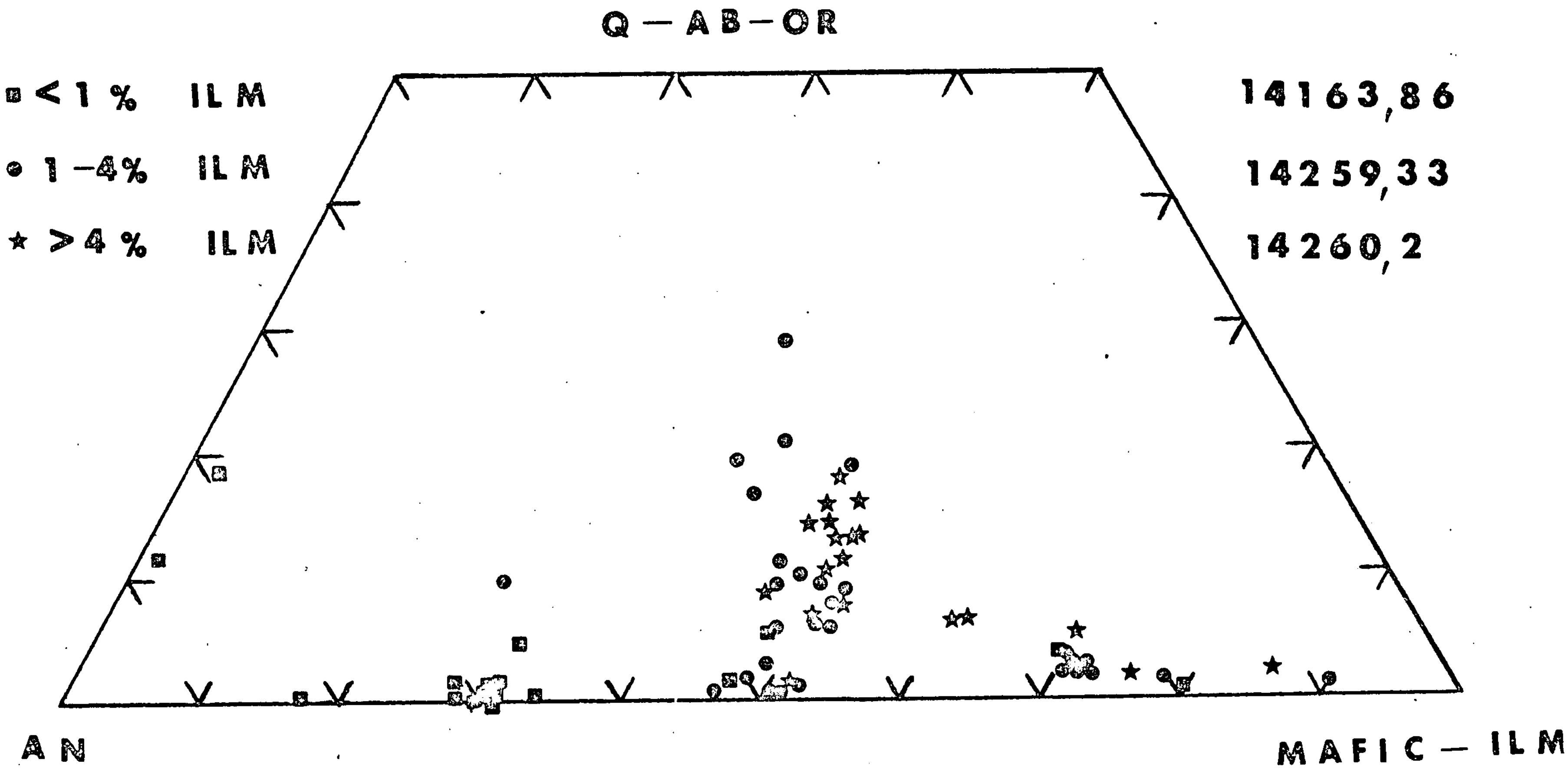


Figure 2D

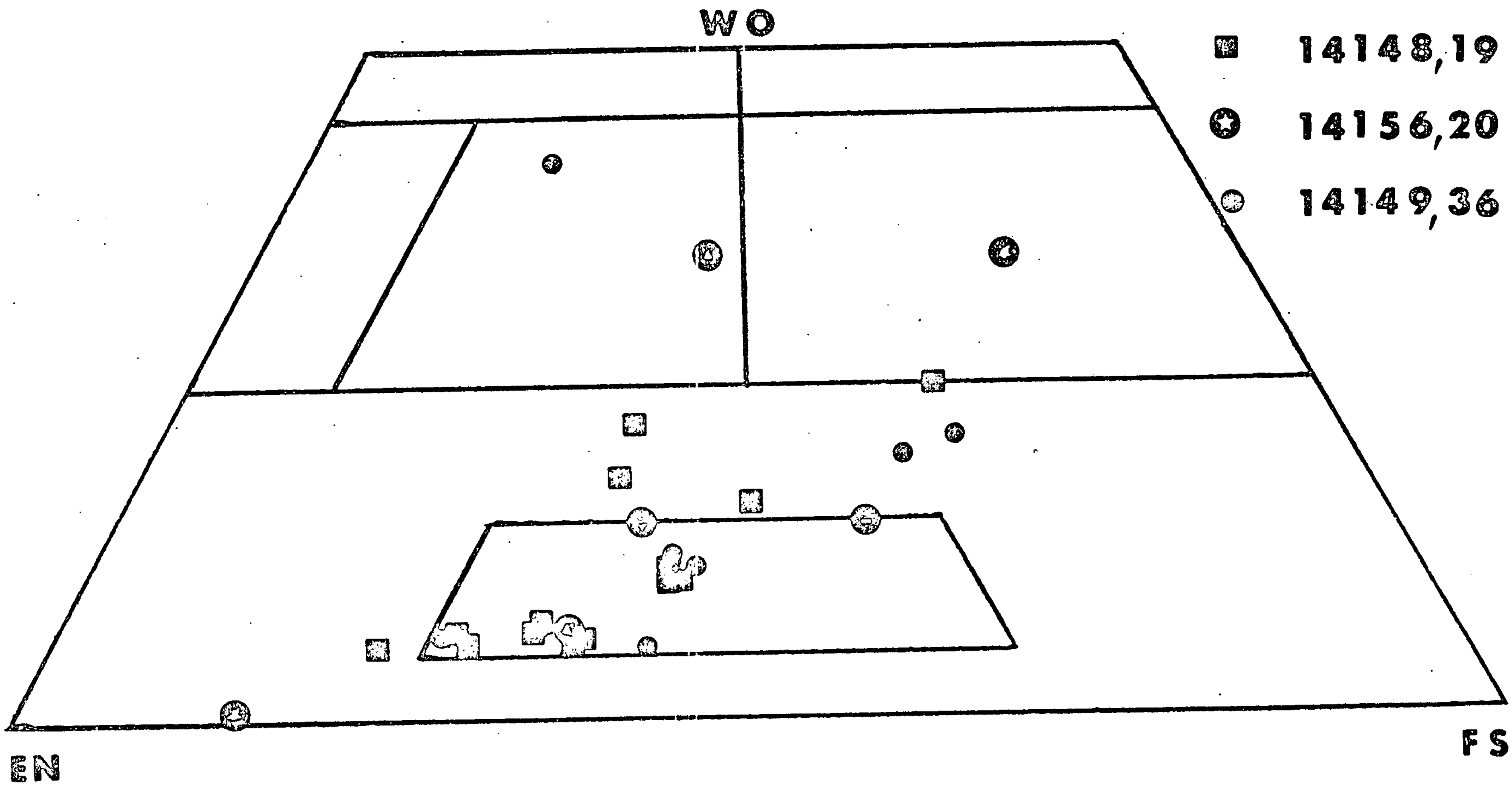
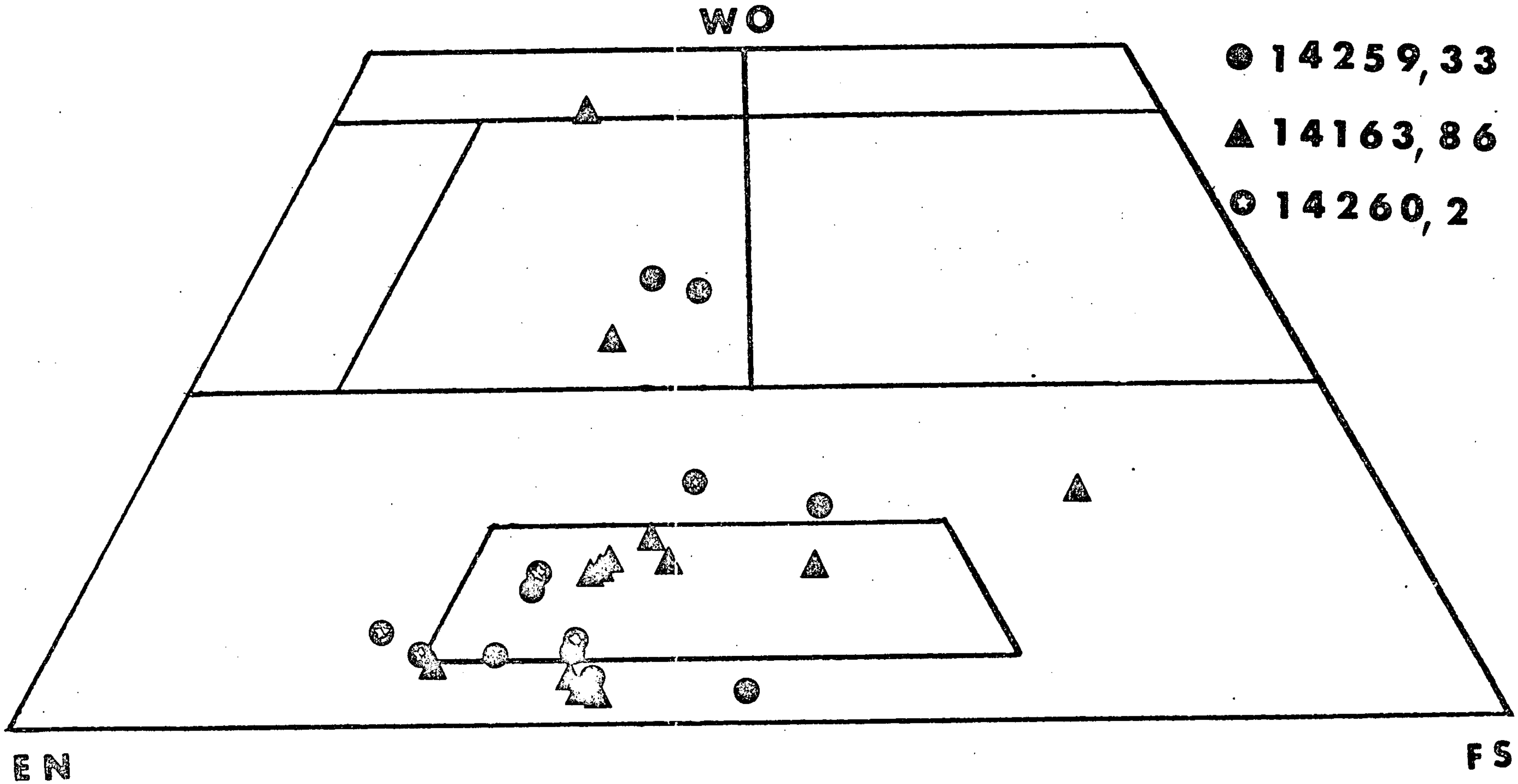


Figure 3A

Figure 3B



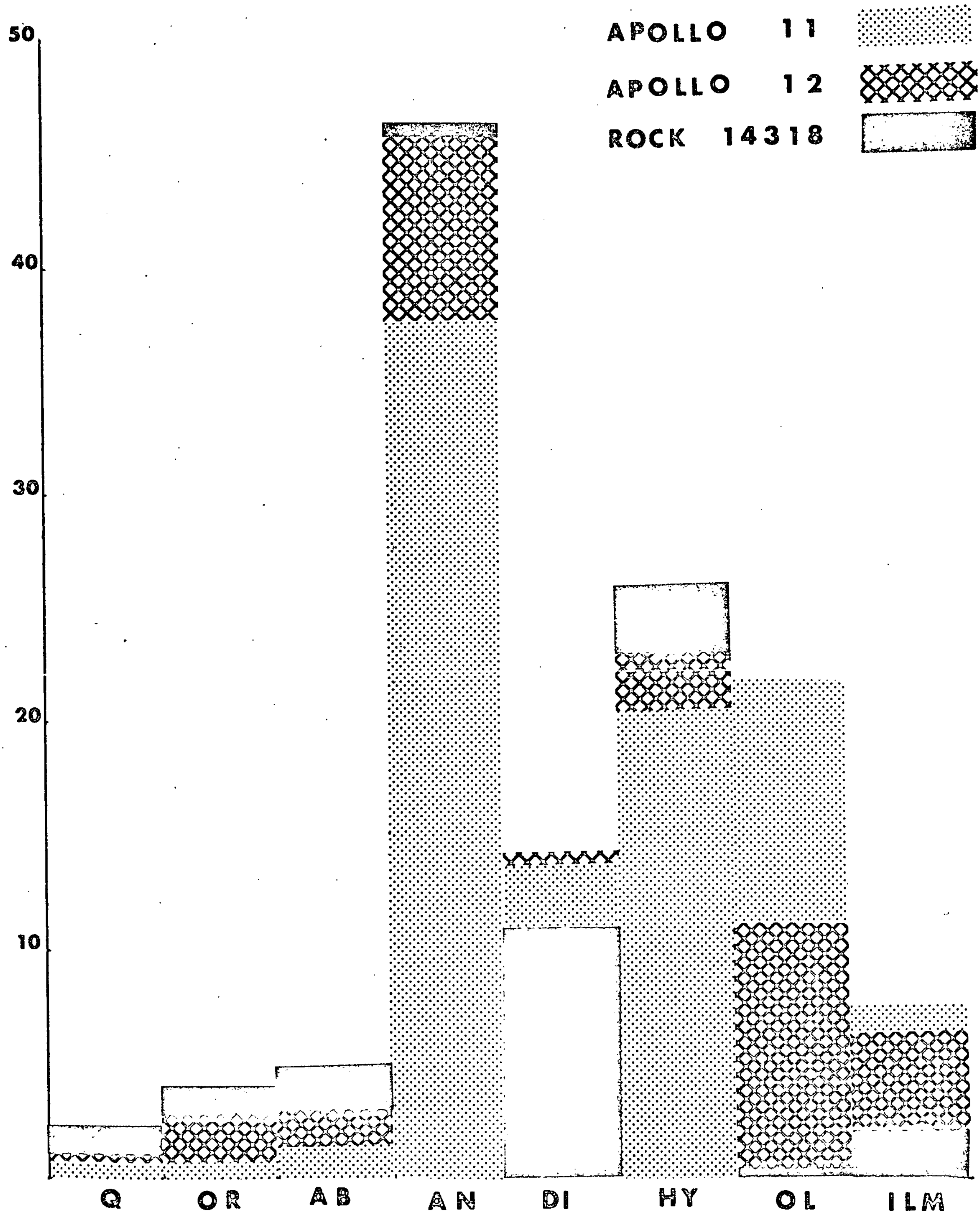

APOLLO 11
APOLLO 12
ROCK 14318
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Figure 4

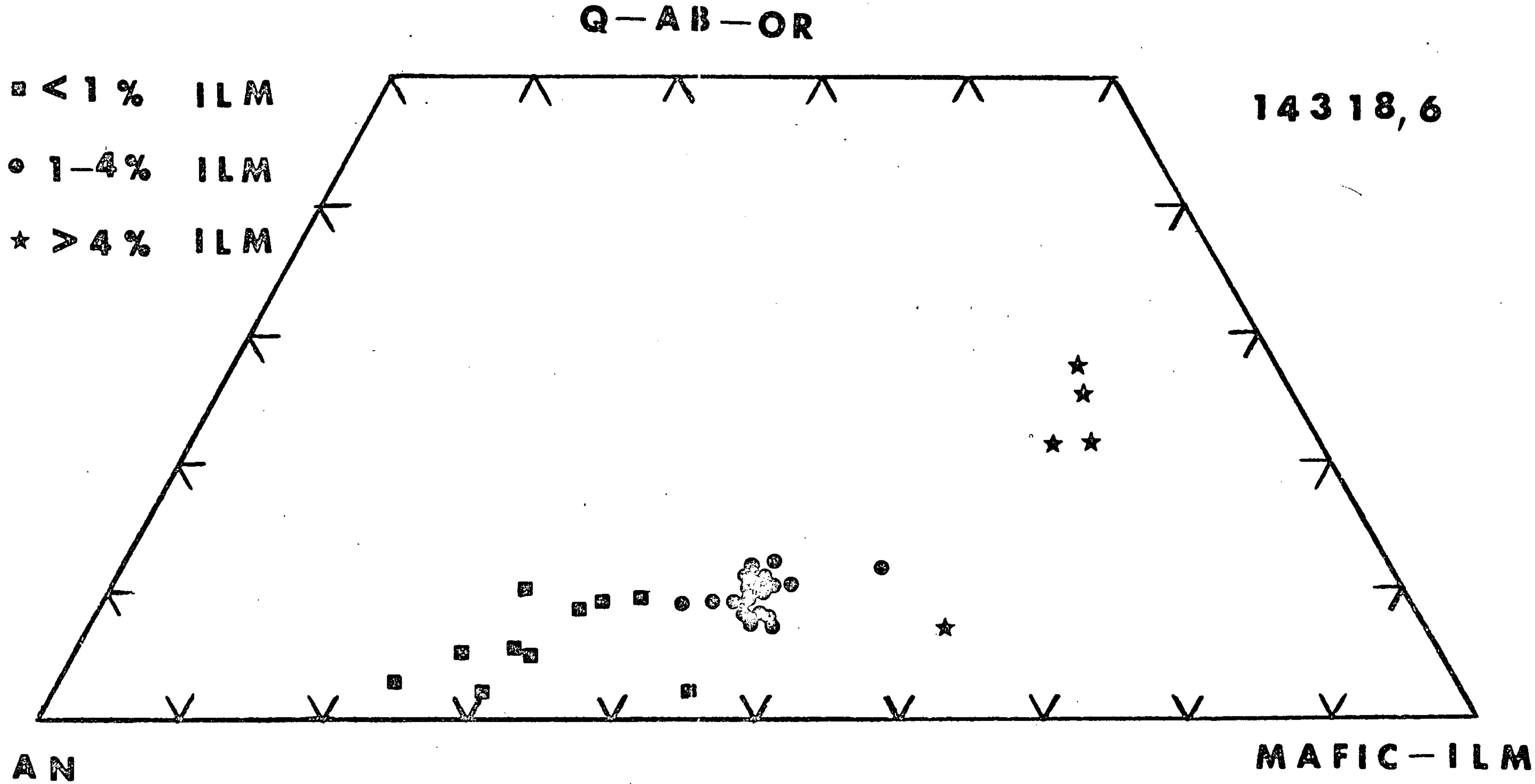

Figure 5

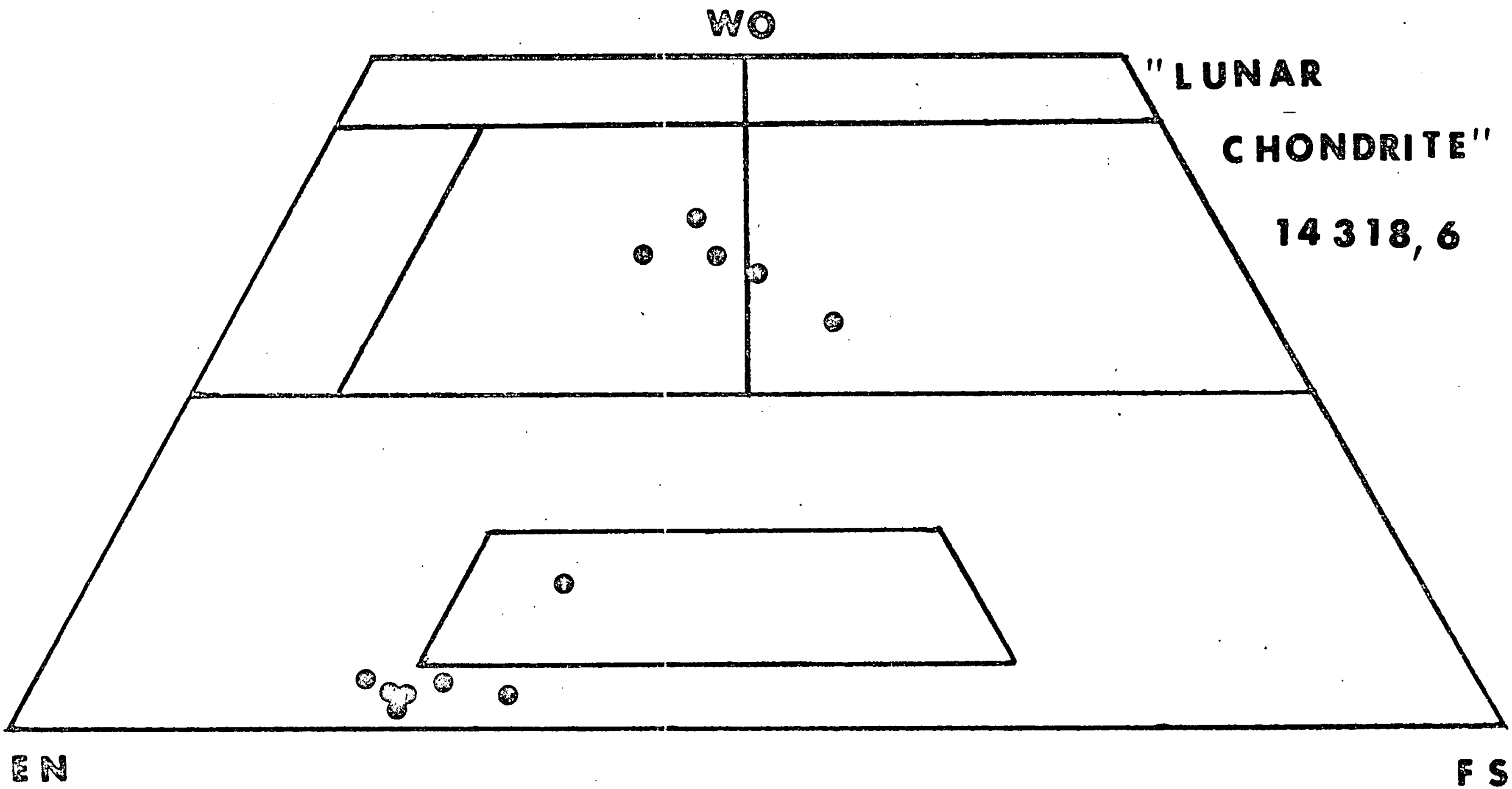

Figure 6

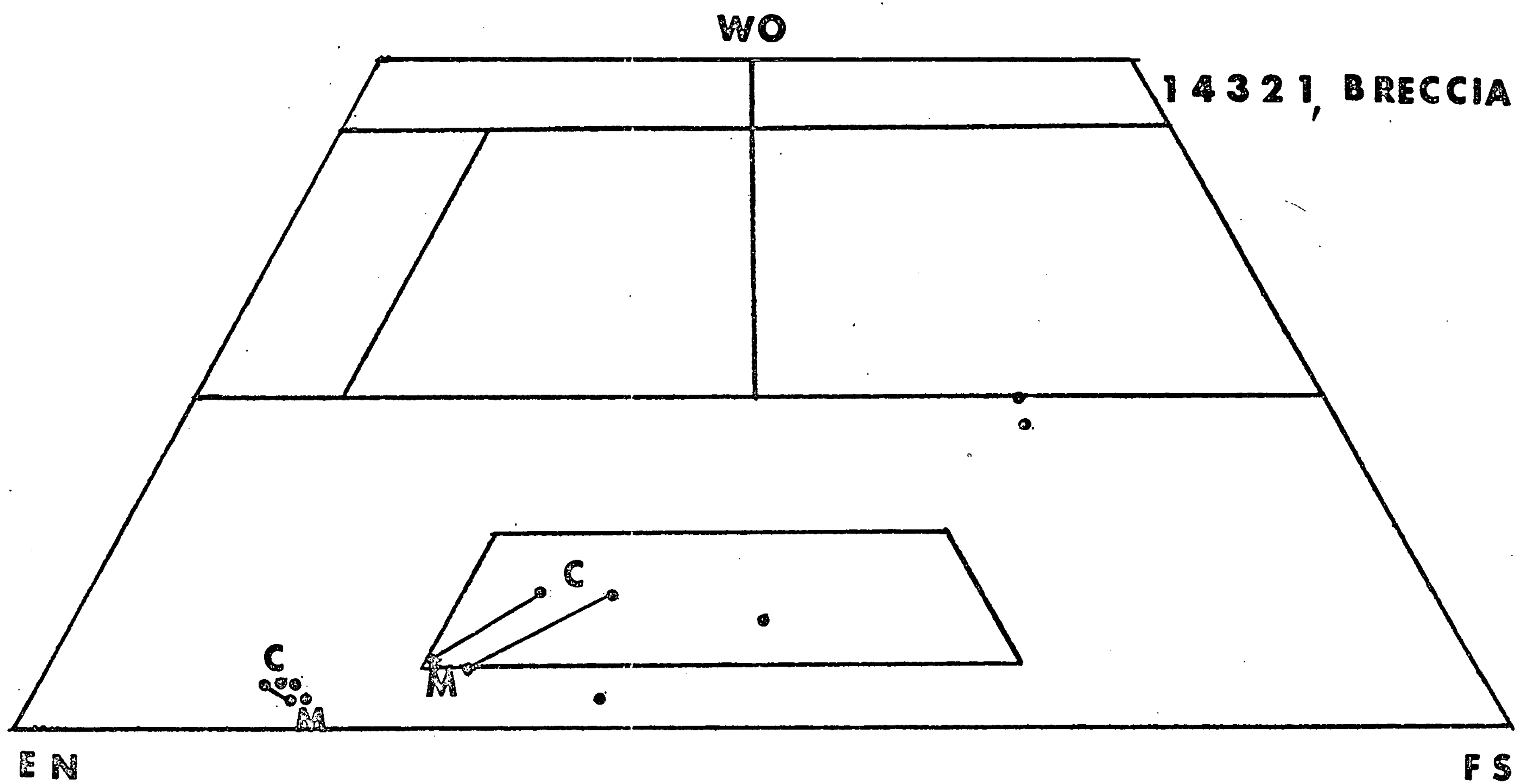

Figure 7

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APPENDIX

TABLE 1

14148,19 TOP TRENCH - GLASS

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O_3	MnO	K_2O	Na_2O	TOTAL
1	11.8	46.4	8.7	4.0	9.2	13.8	0.11	0.77	0.79	95.6
2	4.5	46.9	4.8	0.91	13.1	24.4	0.04	0.50	1.17	96.3
3	0.2	52.7	0.1	0.02	12.7	29.5	0.00	0.53	4.02	99.8
4	11.2	46.1	8.1	2.95	10.6	16.3	0.10	0.41	0.80	96.6
5	10.6	47.6	7.1	2.24	10.4	16.6	0.08	0.90	1.19	96.7
6	10.6	46.8	8.2	2.54	9.4	15.0	0.13	1.15	1.03	94.8
7	9.5	60.5	1.8	2.22	7.3	12.6	0.09	0.91	0.46	95.4
8	12.2	47.2	6.6	1.98	9.6	16.2	0.15	1.48	0.88	96.3
9	0.2	49.3	0.2	0.07	13.6	30.4	0.00	0.70	3.09	97.6
10	10.3	47.5	8.4	2.07	9.0	14.6	0.10	1.38	1.07	94.4
11	10.0	45.2	8.6	1.86	10.6	18.1	0.11	0.47	0.74	95.7
12	10.7	48.6	8.8	2.11	9.4	14.4	0.08	1.15	1.00	96.2
13	11.5	46.5	7.4	2.36	9.7	15.9	0.20	0.74	0.94	95.2
14	8.7	46.4	7.5	3.22	12.8	19.3	0.09	0.05	0.12	98.2
15	19.7	43.2	8.6	4.11	8.8	15.2	0.05	0.36	1.39	101.4
16	13.4	45.6	8.4	2.64	10.5	15.4	0.12	0.32	0.59	97.0
17	5.7	43.4	8.4	0.24	14.9	25.2	0.06	0.00	0.07	98.0
18	10.8	43.6	10.9	2.05	11.5	18.4	0.12	0.11	0.17	97.6
19	5.0	43.8	7.9	0.25	15.3	25.5	0.01	0.03	0.13	97.9
20	11.0	48.9	10.5	1.92	9.0	14.1	0.12	0.39	0.43	96.4
21	23.2	41.3	10.7	4.10	9.2	8.6	0.22	0.16	0.18	97.7
22	23.5	41.6	10.6	4.07	8.8	8.6	0.21	0.14	0.23	97.8
23	22.0	42.0	12.1	4.25	9.0	8.6	0.25	0.07	0.10	98.4
24	6.1	43.5	8.3	0.36	14.4	24.3	0.04	0.06	0.18	97.2
25	5.7	43.2	8.3	0.25	14.5	24.8	0.05	0.00	0.08	96.9
26	13.5	45.8	11.4	2.03	8.7	13.8	0.15	0.24	0.78	96.4
27	14.9	45.6	6.7	2.53	13.0	12.8	0.15	0.34	0.38	96.4

TABLE 1a

1414819 TOP TRENCH GLASS NORM ANALYSES

SAMPLE	Q	OR	AB	AN	DI	HY	OL	IL
1	2.20	4.55	6.69	31.84	11.29	31.40		7.60
2	0.95	2.95	9.90	59.85	4.18	16.76		1.73
3	0.05	3.13	34.02	61.71	1.09	0.04		0.04
4	0.65	2.42	6.77	39.68	10.60	30.84		5.60
5	0.20	5.32	10.07	37.30	11.79	27.78		4.25
6		6.80	8.63	32.96	11.22	30.39	0.03	4.82
7	31.09	5.38	3.89	29.63	5.65	15.53		4.22
8		8.75	7.45	35.88	9.77	29.84	0.84	3.76
9		4.14	24.72	67.01	0.37		0.41	0.13
10		8.16	9.05	30.96	11.22	31.10		3.93
11		2.78	6.26	44.68	6.47	27.11	4.85	3.53
12	0.98	6.80	8.46	31.41	12.48	32.11		4.01
13	0.78	4.37	7.95	36.98	9.20	31.47		4.48
14	4.46	0.30	1.02	51.98	9.37	24.94		6.12
15		2.13	11.76	34.17	7.93	10.78	26.82	7.81
16		1.89	4.99	38.43	11.30	34.09	1.25	5.01
17			0.59	68.45	4.43	11.15	12.90	0.46
18		0.65	1.44	49.12	6.46	23.84	12.25	3.89
19		0.18	1.10	68.91	5.65	10.86	10.76	0.47
20	4.11	2.30	3.64	35.39	7.56	39.71		3.65
21		0.95	1.52	22.19	19.61	24.15	21.46	7.79
22		0.83	1.95	22.02	18.11	26.87	20.26	7.73
23		0.41	0.85	22.81	18.14	28.68	19.41	8.07
24		0.35	1.52	65.32	4.96	12.40	12.00	0.68
25			0.68	67.31	3.74	13.29	11.38	0.47
26		1.42	6.60	33.45	7.97	34.70	8.41	3.86
27	0.53	2.01	3.22	32.22	27.02	26.61		4.81

TABLE 2

14148,19 TOP TRENCH - PYROXENE

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O_3	MnO	TOTAL	En	Fs	Wo	TOTAL
1	18.5	51.3	23.8	0.77	1.42	1.01	0.21	97.0	59	34	3	96
2	20.1	50.3	19.3	0.88	4.99	1.27	0.28	97.1	48	37	10	95
3	18.4	50.9	23.4	0.60	2.29	1.14	0.24	96.9	58	34	5	97
4	20.2	50.8	20.8	0.93	3.97	1.45	0.24	98.4	52	37	8	97
5	10.5	52.9	28.9	0.55	1.35	3.52	0.12	97.9	72	19	3	94
6	20.5	50.9	20.1	0.82	5.05	1.36	0.23	99.0	50	38	10	98
7	18.0	50.7	19.6	0.32	11.0	1.79	0.24	101.7	49	33	23	105
8	20.4	49.6	15.8	0.79	6.9	1.49	0.29	95.3	39	37	14	90
9	14.0	51.7	26.2	1.22	2.16	1.41	0.18	96.9	65	26	4	95
10	14.7	52.5	26.1	1.07	2.03	1.26	0.19	97.9	65	27	4	96
11	14.8	49.6	17.0	0.51	10.2	2.02	0.24	94.3	42	27	21	90
12	28.0	46.5	9.0	1.07	10.6	1.30	0.42	96.8	22	51	22	95
13	16.5	50.5	23.8	1.04	2.19	1.43	0.19	95.7	59	30	5	94
14	17.2	51.6	24.1	0.90	1.90	1.11	0.20	97.0	60	32	4	96

14148,19 TOP TRENCH - PLAGIOCLASE

SAMPLE	FeO	SiO_2	MgO	CaO	Al_2O_3	K_2O	Na_2O	TOTAL
1	0.76	43.8	0.70	18.4	33.3	0.01	0.61	97.6
2	0.17	45.8	0.12	16.8	33.0	0.19	1.73	97.8
3	0.15	43.2	0.16	19.1	35.2	0.08	0.56	98.5
4	0.01	43.8	0.08	19.0	35.5	0.03	0.80	99.2
5	0.28	47.0	0.14	16.0	32.8	0.10	2.23	98.6
6	0.52	45.4	0.36	18.5	32.9	0.08	0.84	98.6
7	0.14	44.0	0.11	19.1	35.7	0.04	0.56	99.6
8	0.16	43.7	0.18	19.5	34.8	0.10	0.58	99.0
9	0.09	43.6	0.08	19.0	35.3	0.08	0.60	98.8
10	0.14	45.5	0.07	17.6	34.2	0.16	1.64	99.3
11	0.16	45.1	0.09	17.7	33.3	0.20	1.51	98.1
12	0.16	43.7	0.24	18.8	34.9	0.10	0.76	98.7
13	0.08	43.2	0.09	19.6	35.2	0.07	0.45	98.7
14	0.15	45.7	0.11	16.8	32.6	0.17	1.84	97.4
15	0.03	44.1	0.13	17.4	34.1	0.11	1.18	97.1

TABLE 3

14149,36 BOTTOM TRENCH - GLASS

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O_3	MnO	K_2O	Na_2O	TOTAL
1	1.16	76.3	0.14	1.16	0.77	11.2	lt 0.05	6.53	0.81	98.1
2	1.22	46.3	0.74	0.12	16.6	33.6	0.00	1.75	1.04	101.4
3	12.4	47.6	7.2	2.28	10.0	15.0	0.16	1.06	0.95	96.6
4	10.8	45.9	9.7	1.91	11.1	17.2	0.16	0.50	0.59	97.9
5	12.7	46.0	9.1	4.60	8.8	12.8	0.13	0.88	0.77	95.8
6	10.3	45.3	8.2	0.92	11.3	20.1	0.16	0.60	0.51	97.4
7	9.7	53.3	4.8	1.61	8.6	15.7	0.13	2.15	0.46	96.5
8	9.6	47.7	7.2	1.99	10.5	17.9	0.11	0.94	0.93	96.9
9	31.6	45.0	5.0	1.39	10.7	1.92	0.39	0.17	0.00	96.2
10	41.5	45.3	3.4	0.95	6.4	0.96	0.44	0.19	0.00	99.1
11	40.9	47.2	4.3	0.90	7.5	1.14	0.40	0.17	0.00	102.5
12	17.9	45.6	15.4	0.56	8.9	9.8	0.23	0.18	0.12	98.7
13	4.4	44.2	5.2	0.75	15.9	28.4	0.05	0.09	0.16	99.2
14	32.7	45.4	6.3	1.51	10.7	2.58	0.52	0.18	0.00	99.9
15	15.4	44.6	8.6	2.38	10.9	13.7	0.22	0.37	0.38	96.6
16	10.9	45.9	11.8	1.33	9.8	14.9	0.14	0.34	0.50	95.6
17	9.4	41.6	10.8	1.69	12.5	21.2	0.08	0.09	0.00	97.4

TABLE 3a

14149,36 BOTTOM TRENCH GLASS NORM ANALYSES

SAMPLE	Q	OR	AB	AN	DI	HY	OL	IL
1	44.60	38.59	6.85	3.82		.66		2.20
2		10.34	2.29	81.85	.42		2.71	.23
3	.54	6.26	8.04	33.54	13.33	30.61		4.33
4		2.95	4.99	42.81	10.03	25.94	7.51	3.63
5	1.65	5.20	6.52	28.87	12.09	32.71		8.74
6		3.55	4.32	50.79	4.34	23.50	9.16	1.75
7	11.58	12.71	3.89	34.43	6.88	23.91		3.06
8	1.04	5.56	7.87	41.89	8.38	28.36		3.78
9		1.00		4.74	41.88	41.80	4.11	2.64
10		1.12		2.06	26.05	61.07	7.04	1.80
11		1.00		2.61	30.23	59.46	7.50	1.71
12		1.06	1.02	25.67	15.21	31.10	23.57	1.06
13		.53	1.35	76.51	1.92	13.32	4.09	1.42
14		1.06		6.51	40.16	36.20	13.10	2.87
15		2.19	3.22	34.58	16.21	29.41	6.43	4.52
16		2.01	4.23	37.41	9.13	33.05	7.25	2.53
17		.53		57.58	3.60	13.03	19.41	3.21

TABLE 4

14149,36 BOTTOM TRENCH - PYROXENE

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O_3	MnO	TOTAL	En	Fs	Wo	TOTAL
1	14.4	52.7	25.9	0.58	1.77	2.00	0.16	97.6	65	26	4	95
2	28.1	48.0	9.8	0.86	8.9	1.03	0.45	97.2	24	52	18	94
3	20.0	51.6	22.2	0.76	2.52	1.22	0.25	98.6	55	37	5	97
4	26.6	48.0	11.8	1.18	10.2	1.32	0.26	99.4	29	49	21	99
5	7.6	48.9	15.3	2.15	20.1	2.70	0.13	96.9	38	14	42	94
6	21.1	50.3	19.0	1.02	6.40	1.42	0.20	99.4	47	39	13	99
7	20.5	50.2	18.9	0.78	5.00	1.29	0.30	97.0	47	38	10	95

14149,36 BOTTOM TRENCH - OLIVINE

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	MnO	TOTAL
1	30.1	36.1	32.2	0.04	0.33	0.26	99.0
2	28.9	36.0	34.2	0.04	0.19	0.23	99.6
3	30.5	36.0	32.4	0.05	0.34	0.30	99.6

14149,36 BOTTOM TRENCH - PLAGIOCLASE

SAMPLE	FeO	SiO_2	MgO	CaO	Al_2O_3	K_2O	Na_2O	TOTAL
1	0.23	45.4	0.18	18.4	35.4	0.07	0.70	100.4
2	0.19	43.8	0.18	18.4	34.6	0.08	0.50	97.8
3	0.37	43.7	0.06	18.6	34.5	0.12	0.67	98.1
4	0.17	43.4	0.14	18.7	35.4	0.09	0.45	98.4
5	0.16	43.6	0.27	18.7	35.6	0.12	0.75	99.2
6	0.24	44.1	0.27	18.5	34.8	0.22	0.76	98.9
7	0.24	45.0	0.16	18.8	35.0	0.09	0.82	100.1

TABLE 5

14156,20 MIDDLE TRENCH - GLASS

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O	MnO	K_2O	Na_2O	TOTAL
1	12.2	45.4	9.9	2.50	12.7	10.4	0.12	1.39	0.71	95.3
2	11.3	46.1	11.6	1.48	8.3	14.0	0.14	0.64	0.79	94.4
3	10.6	46.4	10.5	2.03	9.5	15.9	0.13	0.73	0.82	96.6
4	11.9	45.8	8.7	3.73	9.3	14.4	0.12	0.76	0.81	95.5
5	10.8	47.9	6.8	2.46	10.4	16.0	0.12	0.71	0.86	96.0
6	11.7	46.9	8.0	2.39	10.8	16.3	0.12	0.58	0.63	97.4
7	8.3	46.4	7.5	2.00	11.5	19.0	0.09	0.54	0.96	96.3
8	11.0	45.0	9.6	1.45	9.8	15.9	0.13	0.52	0.66	94.1
9	11.8	45.8	9.0	4.20	8.7	14.0	0.13	1.01	0.94	95.6
10	11.7	46.1	10.0	2.21	9.7	16.2	0.12	0.47	0.56	97.1
11	9.6	50.6	4.8	1.47	10.8	17.6	0.10	0.73	0.89	96.6
12	10.0	46.5	9.6	1.91	10.0	16.9	0.12	0.59	0.79	96.4
13	11.2	46.6	8.4	3.62	9.0	14.6	0.11	0.98	0.92	95.4
14	12.7	49.2	4.8	2.55	9.2	12.6	0.13	1.48	1.15	93.8
15	10.1	45.8	9.4	1.81	10.9	18.3	0.10	0.43	0.51	97.4
16	6.1	43.5	8.0	0.33	14.9	24.6	0.06	0.05	0.14	97.7
17	7.4	43.7	9.4	0.32	14.6	24.8	0.07	0.06	0.15	100.5
18	4.6	43.5	3.9	0.32	14.7	23.5	0.06	0.07	0.23	90.9
19	6.1	42.9	8.4	0.26	14.3	24.9	0.04	0.03	0.08	97.0
20	6.0	43.4	8.0	0.32	15.0	24.9	0.07	0.06	0.16	97.9

TABLE 5a

14156,20 MIDDLE TRENCH - GLASS NORM ANALYSES

SAMPLE	Q	OR	AB	AN	DI	HY	OL	IL
1		8.21	6.01	21.09	34.36	6.22	14.68	4.75
2		3.78	6.69	32.77	6.86	34.30	7.14	2.81
3		4.31	7.02	37.50	7.85	29.11	6.97	3.86
4	.78	4.49	6.85	33.41	10.42	32.47		7.08
5	3.48	4.20	7.28	37.70	11.47	27.25		4.67
6	.81	3.43	5.33	39.94	11.25	32.14		4.54
7		3.19	8.12	45.94	9.07	25.67	.50	3.80
8		3.07	5.58	38.89	7.98	29.64	6.15	2.75
9	.22	5.97	7.95	31.00	9.93	32.53		7.98
10		2.78	4.74	40.30	6.40	35.43	3.21	4.20
11	7.85	4.31	7.53	41.87	9.77	22.46		2.79
12		3.49	6.69	40.83	7.17	31.33	3.28	3.63
13	1.51	5.79	7.79	32.82	9.68	30.97		6.88
14	5.65	8.75	9.73	24.85	17.49	22.50		4.84
15		2.54	4.32	46.38	6.29	29.84	4.55	3.44
16		0.30	1.18	66.35	6.14	10.83	12.26	0.63
17		0.35	1.27	66.82	4.56	6.98	19.91	0.61
18	3.09	0.41	1.95	62.89	8.26	13.68		0.61
19		0.18	0.68	67.50	2.79	12.07	13.30	0.49
20		0.35	1.35	67.05	5.98	9.15	13.42	0.61

TABLE 6

14156,20 MIDDLE TRENCH - PYROXENE

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O_3	MnO	TOTAL	En	Fs	Wo	TOTAL
1	26.2	46.7	5.5	0.98	17.5	0.98	0.34	98.2	14	48	36	98
2	18.6	50.0	19.2	0.77	5.7	1.35	0.28	95.9	48	34	12	94
3	6.3	55.7	33.8	0.04	0.21	0.25	0.08	96.4	84	12	0	96
4	17.3	51.9	24.4	1.13	2.11	1.20	0.21	98.2	61	32	4	97
5	15.5	48.2	13.4	2.30	16.9	2.70	0.25	99.3	33	28	35	96
6	28.4	48.6	13.5	0.85	5.8	1.19	0.42	98.8	34	52	12	98

14156,20 MIDDLE TRENCH - PLAGIOCLASE

SAMPLE	FeO	SiO_2	MgO	CaO	Al_2O_3	K_2O	Na_2O	TOTAL
1	0.12	43.6	0.09	19.1	34.1	0.74	1.34	99.1
2	0.04	43.1	0.07	19.2	35.1	0.17	0.61	98.3
3	0.37	43.6	0.23	19.0	33.9	0.08	0.91	98.1
4	0.16	44.6	0.24	19.5	34.4	0.13	0.71	99.7

TABLE 7

14163,86 FINES < 1 mm - GLASS

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O_3	MnO	K_2O	Na_2O	TOTAL
1	10.7	46.2	10.5	1.84	12.3	19.1	0.16	0.14	0.10	101.0
2	18.2	47.5	14.6	0.54	10.2	10.4	0.28	0.17	0.30	102.2
3	12.7	49.0	7.9	2.62	10.8	15.6	0.18	0.86	0.77	100.4
4	10.7	47.4	10.4	1.74	11.6	18.1	0.14	0.39	0.34	100.8
5	lt .01	47.6	.08	lt .05	18.4	34.8	lt 0.05	0.11	1.52	102.5
6	11.0	47.4	10.3	1.78	11.9	18.5	0.16	0.18	0.18	101.4
7	9.3	52.2	9.8	1.32	10.9	16.7	0.16	0.28	0.32	101.0

TABLE 7a

14163,86 NORM GLASS ANALYSES

SAMPLE	Q	OR	AB	AN	DI	HY	OL	IL
1		0.83	0.85	51.26	7.97	29.89	6.76	3.49
2		1.00	2.54	26.53	19.86	28.06	23.18	1.03
3	1.18	5.08	6.52	36.57	14.06	32.04		4.98
4		2.30	2.88	46.71	8.85	31.80	4.97	3.30
5		0.65	11.72	87.81	0.48			0.09

TABLE 8

14163,86 PYROXENE

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O_3	TOTAL	En	Fs	Wo	TOTAL
1	20.0	51.9	24.3	0.34	1.16	0.42	98.1	61	37	2	100
2	19.6	52.3	24.1	0.33	1.33	0.96	98.6	60	36	3	99
3	20.0	52.4	24.1	0.35	1.29	0.40	98.5	60	37	3	100
4	18.3	52.1	21.8	0.40	5.4	1.54	99.5	54	34	11	99
5	8.5	51.8	15.4	0.49	22.4	0.87	99.5	38	16	46	100
6	14.3	53.9	29.0	0.38	1.7	0.77	100.0	72	26	4	102

14163,86 OLIVINE

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	MnO	TOTAL
1	25.6	37.5	36.2	0.05-0.1	0.55	0.29	100.1
2	13.2	40.1	44.6	0.05-0.1	0.25	0.15	98.3

14163,86 PLAGIOCLASE AND FELDSPAR

SAMPLE	FeO	SiO_2	MgO	CaO	Al_2O_3	K_2O	Na_2O	TOTAL
1	lt 0.1	48.6	0.11	17.2	33.8	0.27	1.98	102.0
2	lt 0.1	46.6	0.12	18.5	35.2	0.40	1.29	102.1
3	lt 0.01	48.5	0.09	17.6	34.2	0.17	1.78	102.3
4	lt 0.01	48.0	0.06	17.7	34.1	0.13	1.76	101.8
5	lt 0.01	48.5	0.08	17.7	34.2	0.18	1.82	102.5
6	lt 0.01	48.1	0.10	17.9	34.3	0.18	1.84	102.4
7	lt 0.05	46.5	0.37	18.9	34.7	0.07	1.09	101.6
8	lt 0.05	47.6	0.13	18.4	34.4	0.12	1.43	102.1
9	lt 0.01	62.3	0.02	0.5	19.7	14.4	0.62	97.5

TABLE 8 (cont'd)

14163,86 - ILMENITE, METAL, SULFIDE

SAMPLE	FeO	TiO_2	MgO	Cr_2O_3	MnO	Fe	Ni	Co	S	TOTAL
1	42.5	53.9	3.6	.4	.3					100.7
2	41.4	53.5	3.9	.4	.3					99.5
3						92.2	6.0	.44		98.6
4						93.6	8.3	.35		102.2
5						92.2	7.0	.41		99.6
6						90.1	7.0	.70		97.8
7						63.3			36.1	99.4

14163,86 - SPINEL

FeO	MgO	TiO_2	Cr_2O_3	Al_2O_3	TOTAL
10.4	20.4	0.4	8.2	61.0	100.4

14163,86 - BADDELEYITE

ZrO_2	FeO	TiO_2	MgO	HfO_2	CeO	Y_2O_3
Major	1.67	2.50	0.3	0.94	0.3	<0.1

TABLE 9

14163,86 - COARSE CRYSTALLINE FRAGMENT WITH ZONED PYROXENE, PLAGIOCLASE, FELDSPAR, APATITE, WHITLOCKITE and BADDELEYITE

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O_3	TOTAL	En	Fs	Wo	TOTAL
Pyroxene 1	33.6	46.0	7.7	0.91	7.0	1.12	96.3	19	62	15	96
	25.6	49.1	15.7	0.61	5.6	0.73	97.3	39	47	12	98
Pyroxene 2	20.9	49.1	18.7	0.96	5.7	1.26	96.6	47	38	12	97
	19.5	49.9	19.9	0.86	6.2	1.31	97.7	50	36	13	99
	17.2	51.4	22.5	0.74	4.7	1.39	97.9	56	32	10	98
	16.6	51.0	22.0	0.74	5.5	1.58	97.4	55	30	11	96
Pyroxene 3	13.5	49.8	17.3	1.25	13.1	2.19	97.1	43	25	27	95

SAMPLE	FeO	SiO_2	CaO	Al_2O_3	K_2O	Na_2O	TOTAL
Feldspar	0.18	62.0	0.68	19.2	12.9	1.39	96.4
Plag. 1							
center	0.26	45.5	19.0	35.4	lt .10	0.43	100.6
Margin	0.19	45.7	15.3	35.6	0.40	2.54	99.7
Plag. 2							
center	0.19	45.0	18.5	35.6	lt .10	0.53	99.8
Margin	0.43	44.4	18.2	33.7	0.15	1.16	98.0
Plag. 3							
center	0.33	45.7	17.8	34.7	0.19	1.22	99.9

SAMPLE	ZrO_2	FeO	HfO_2
Baddeleyite	Major	0.85	1.3

TABLE 9 (cont'd)

SAMPLE	CaO	P_2O_5	FeO	MgO	SiO_2	Na_2O	Al_2O_3	Cl	F
Apatite	53.3	41.7	0.49	lt 0.05	1.00	0.10	0.60	lt 0.10	3.6
Whitlockite #1	40.0	42.2	4.44	1.26	1.28	0.35	0.23	lt 0.10	0.2
Whitlockite #2	–	–	4.12	–	1.20	0.18	0.11	0.12	0.2

(cont'd)

SAMPLE	La_2O_3	Ce_2O_3	Pr_2O_3	Nd_2O_3	Sm_2O_3	Gd_2O_3	Dy_2O_3	Y_2O_3	TOTAL
Apatite	0.10	0.23	0.03	0.10					101.2
Whitlockite #1	0.81	1.88	0.40	1.05	0.44	0.50	0.50	2.06	97.6
Whitlockite #2	1.02	2.35	0.55	1.34	0.52	0.62	0.63	1.62	

TABLE 10

14259,33 FINES < 1mm GLASS

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O_3	MnO	K_2O	Na_2O	TOTAL
1	10.6	46.8	9.7	1.72	11.9	19.7	0.15	0.31	0.32	101.2
2	19.2	46.2	7.7	2.85	10.8	12.8	0.22	0.28	0.56	100.6
3	18.3	47.0	15.3	0.54	9.7	10.2	0.25	0.20	0.26	101.8
4	11.6	47.6	10.6	1.72	11.5	18.2	0.17	0.26	0.17	101.8
5	13.0	47.2	8.2	2.36	11.7	16.2	0.19	0.48	0.55	99.9
6	10.0	48.3	9.4	2.12	11.7	18.2	0.16	0.62	0.58	101.1
7	10.8	47.5	10.0	2.05	11.4	18.0	0.16	0.39	0.51	100.8
8	10.7	47.6	9.3	1.88	11.1	18.2	0.15	0.41	0.46	99.8
9	lt .2	49.2	lt .2	0.14	16.1	33.2	lt .1	0.26	1.45	100.4
10	0.6	55.9	6.8	1.52	9.6	22.6	lt .1	1.30	2.68	101.0
11	13.1	52.0	16.9	0.93	14.1	3.3	0.21	0.07	0.06	100.7
12	5.6	45.4	9.3	0.29	15.2	26.0	0.09	0.08	lt .01	102.0
13	15.5	48.1	9.3	2.67	10.5	13.4	0.19	0.37	0.46	100.5
14	5.9	45.3	8.9	0.26	15.0	26.4	0.08	0.12	lt .1	102.0
15	6.6	47.8	7.2	0.40	14.3	24.6	0.09	0.34	0.29	101.6
16	6.0	46.0	7.5	0.31	15.0	25.3	0.08	0.09	lt .1	100.3
17	12.4	48.9	7.8	2.64	10.6	16.1	0.13	0.69	0.94	100.2
18	12.1	49.0	7.8	2.61	10.9	16.3	0.13	0.83	1.02	100.7
19	10.5	48.2	9.7	1.67	10.9	18.3	0.10	0.41	0.61	100.4
20	9.8	49.5	9.8	1.63	11.5	17.9	0.12	0.55	0.74	101.5
21	10.4	49.4	9.7	1.76	11.3	18.2	0.11	0.47	0.69	102.0
22	2.8	77.3	0.1	0.20	1.4	12.1	0.06	4.07	0.23	98.3
23	10.4	47.7	9.4	2.03	11.9	18.5	0.15	0.46	0.75	101.3
24	13.6	44.9	12.8	1.33	10.3	15.9	0.16	0.40	0.73	100.1
25	9.8	48.6	10.1	1.75	11.2	20.0	0.11	0.34	0.67	102.6
26	9.5	48.2	9.7	2.18	11.5	16.6	0.11	0.63	0.82	99.2

TABLE 10a

14259,33 - GLASS NORM ANALYSES

SAMPLE	Q	OR	AB	AN	DI	HY	OL	IL
2		1.65	4.74	31.59	18.49	32.59	6.13	5.41
3		1.18	2.20	26.08	18.16	27.67	25.44	1.03
5		2.84	4.65	40.32	14.67	31.36	1.57	4.48
6		3.66	4.91	45.23	10.46	31.01	1.79	4.03
9	4.82	1.54	12.27	79.87		0.82		0.27
11		0.41	0.51	8.53	49.85	36.45	3.15	1.77
13	0.57	2.19	3.89	33.41	15.49	39.88		5.07
15		2.01	2.45	64.82	5.00	25.14	1.44	0.76
16		0.53	0.85	68.32	4.95	20.39	4.75	0.59
17	1.18	4.08	7.95	37.67	12.32	31.98		5.01
18	0.23	4.91	8.63	37.45	13.73	30.79		4.96
20		3.25	6.26	43.90	10.73	33.26	1.05	3.10
22	54.99	24.05	1.95	6.95		5.17		0.38
24		2.36	6.18	38.93	9.96	13.27	26.90	2.53
26		3.72	6.94	39.76	14.07	28.63	1.98	4.14

TABLE 11

14259,33 PYROXENE

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O_3	MnO	TOTAL	En	Fs	Wo	TOTAL
1	16.3	50.4	15.4	1.48	15.0	2.6	lt .01	101.2	38	30	31	99
2	24.6	51.4	15.1	0.64	7.3	0.9	lt .01	99.9	38	45	15	98
3	16.0	53.1	24.0	0.45	4.3	1.9	lt .01	99.8	60	29	9	98
4	16.4	52.7	25.5	0.71	2.20	1.46	0.21	99.2	64	30	5	99
5	18.5	52.2	23.7	0.86	2.37	2.28	0.27	100.2	59	34	5	98
6	26.9	52.2	19.5	0.17	1.29	0.39	0.35	100.8	49	49	3	101
7	20.0	53.0	24.6	0.50	1.63	0.86			61	37	3	101
8	14.6	48.1	16.5	2.11	16.3	2.95			41	27	34	102

14259,33 OLIVINE

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	MnO	TOTAL
1	32.5	36.5	31.4	0.05	0.28		100.7
2	26.8	37.6	35.1		0.29		99.8
3	27.1	37.7	35.3	0.10	0.28		100.5
4	35.6	36.1	28.7		0.50		100.9
5	25.9	37.6	35.5		0.19		99.2
6	29.9	36.1	32.6	lt .1	0.32	0.27	99.2
7	3.2	43.3	53.6	0.17	0.60	0.10	101.0
8	28.1	38.9	34.1	0.14	0.34	0.23	101.8
9	27.6	38.7	34.4	0.19	0.35	0.22	101.5
10	27.8	39.0	34.5	0.18	0.72	0.16	102.4
11	34.2	36.1	30.2	lt .10	0.28		100.8
12	32.1	35.7	29.7				97.5

TABLE 11 (cont'd)

14259,33 PLAGIOCLASE

SAMPLE	FeO	SiO_2	MgO	CaO	Al_2O_3	K_2O	Na_2O	TOTAL
1	lt .1	44.8	lt .1	19.4	37.3	0.17	0.66	102.3
2	lt .01	45.6	.10	19.5	37.6	0.14	0.68	103.6
3	lt .1	45.6	.23	20.0	37.9	0.16	0.54	104.4
4	lt .05	44.5	.15	19.6	37.1	0.17	0.71	102.2
5	lt .01	45.0	.13	20.1	37.6	0.14	0.45	103.4
6	0.3	50.1		15.8	32.6	0.22	2.24	101.3
7	lt .1	45.0		19.1	36.1	0.09	0.54	100.8
8	0.1	47.3		17.2	33.8	0.16	1.33	99.9
9	0.1	47.2		17.4	34.6	0.13	1.26	100.7
10	0.1	47.1		18.2	34.4	0.09	1.42	101.3
11	0.15	44.8	0.14	18.6	34.0	0.17	0.52	98.4
12	0.49	50.3	0.11	15.0	31.3	0.20	2.77	100.2
13	0.31	45.2	0.21	18.7	34.9	0.07	0.67	100.1
14	0.20	45.4	0.24	19.8	35.5	0.10	0.41	101.6
15	0.13	44.3	0.11	19.4	35.7	0.09	0.48	100.2
16	0.15	45.0	0.09	18.3	34.6	0.14	0.78	99.1
17	0.16	44.3	0.11	19.2	35.5	0.19	0.47	99.9
18	0.14	44.7	0.13	18.9	35.8	0.17	0.50	100.3

14259,33 ILMENITE

SAMPLE	FeO	MgO	TiO_2	MnO	Cr_2O_3	TOTAL
	42.6	3.3	53.4	0.2	0.3	99.8

TABLE 12

14260,2 FINES 1mm GLASS

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O_3	MnO	K_2O	Na_2O	TOTAL
1	9.8	49.9	4.9	1.49	10.9	17.6	0.07	0.83	0.87	96.4
2	8.5	50.8	10.0	1.67	9.1	15.4	0.10	1.39	0.98	97.9
3	9.8	47.2	8.0	1.97	10.8	17.4	0.12	0.58	0.68	96.6
4	10.3	47.2	9.2	1.92	10.8	17.3	0.11	0.62	0.73	98.2
5	12.7	48.4	6.3	3.22	10.5	14.0	0.15	0.45	0.24	96.0
6	10.9	48.1	8.4	3.78	9.0	14.8	0.10	0.75	0.75	96.6
7	10.7	46.4	10.5	1.71	10.2	16.5	0.12	0.44	0.56	97.1
8	11.4	51.4	5.0	1.84	10.3	16.0	0.12	0.94	0.78	97.8
9	9.7	47.4	10.4	2.38	9.6	16.2	0.07	0.74	0.79	97.3
10	10.6	46.3	10.1	1.94	10.5	16.7	0.13	0.60	0.64	97.5
11	10.1	47.2	7.4	2.12	10.5	16.9	0.08	0.98	0.96	96.2
12	10.7	47.2	8.4	3.45	9.5	15.5	0.11	0.75	0.69	96.3
13	9.8	47.6	7.1	2.54	10.7	16.3	0.12	0.87	0.95	96.0
14	11.6	47.6	7.4	2.38	10.4	15.8	0.10	0.73	0.73	96.7
15	11.0	49.7	7.0	2.70	10.0	15.3	0.10	0.58	1.06	97.4
16	9.7	52.3	2.9	1.30	10.6	16.1	0.09	1.00	1.80	95.8
17	17.5	45.4	14.7	0.58	9.6	9.9	0.23	0.13	0.19	98.2
18	11.4	44.6	10.6	2.11	11.0	17.5	0.10	0.18	0.08	97.6
19	5.5	44.6	8.5	0.22	14.8	25.6	0.06	0.06	0.06	99.4
20	11.7	46.2	8.0	2.40	11.2	16.9	0.15	0.33	0.42	97.3
21	5.7	43.8	8.8	0.25	14.4	25.4	0.05	0.01	0.01	98.4
22	5.6	43.5	8.6	0.28	15.0	25.9	0.07	0.00	0.00	99.0
23	19.3	44.6	18.8	0.50	8.0	7.3	0.21	0.11	0.07	98.9
24	1.40	42.3	6.6	0.28	18.2	30.4	0.00	0.02	0.00	99.2

TABLE 12 (cont'd)

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O_3	MnO	K_2O	Na_2O	TOTAL
25	5.7	43.8	8.7	0.28	14.5	25.4	0.06	0.05	0.00	98.5
26	5.2	49.6	5.8	0.54	13.4	23.8	0.03	0.30	0.09	98.8
27	17.4	45.6	14.4	0.58	9.3	10.2	0.21	0.12	0.16	98.0
28	5.3	43.8	7.5	0.28	15.2	26.5	0.04	0.10	0.10	98.6
29	10.8	42.1	10.8	2.08	12.3	19.6	0.15	0.09	0.00	97.9
30	12.7	41.3	12.5	1.77	10.9	18.2	0.15	0.09	0.00	97.6
31	17.5	45.4	13.9	0.63	9.7	10.3	0.23	0.17	0.16	98.0
32	17.6	45.0	14.8	0.58	9.4	9.9	0.21	0.16	0.18	97.8
33	5.7	43.6	8.7	0.25	14.5	25.5	0.04	0.07	0.00	98.4
34	19.3	44.2	17.1	0.74	8.5	7.8	0.22	0.11	0.11	98.1
35	20.6	41.7	6.7	7.58	10.4	9.9	0.27	0.18	0.47	97.8
36	5.7	45.0	9.2	0.28	14.8	24.4	0.07	0.06	0.00	99.5
37	5.9	44.3	8.2	0.32	14.8	25.6	0.08	0.08	0.03	99.3
38	11.6	45.2	10.9	1.73	10.9	17.5	0.11	0.09	0.04	98.1
39	4.6	44.5	8.4	0.20	15.4	26.4	0.05	0.00	0.00	99.6
40	24.4	32.8	13.2	16.4	6.8	4.8	0.30	0.22	0.13	99.1
41	18.6	44.1	15.1	2.13	8.8	9.0	0.20	0.13	0.12	98.2
42	11.8	41.1	9.5	1.80	13.3	18.6	0.14	0.12	0.06	96.4
43	9.8	46.5	10.6	1.79	10.3	17.9	0.07	0.23	0.52	97.7
44	10.0	46.3	12.1	1.62	11.0	18.2	0.11	0.14	0.22	99.7
45	17.7	46.1	14.8	0.54	9.3	9.8	0.19	0.15	0.12	98.7
46	10.5	46.2	11.4	1.62	10.1	16.9	0.10	0.39	0.42	97.6
47	11.7	43.0	12.0	1.65	10.9	17.9	0.13	0.11	0.00	97.4
48	10.5	47.6	11.1	2.03	10.0	16.6	0.12	0.25	0.47	98.7

TABLE 12a

14260,2 GLASS NORM ANALYSES

SAMPLE	Q	OR	AB	AN	DI	HY	CL	IL
1	6.70	4.91	7.36	41.67	10.36	22.44		2.83
2	1.95	8.21	8.29	33.52	9.43	33.37		3.17
3	1.49	3.43	5.75	42.71	8.91	30.52		3.74
4		3.66	6.18	42.10	9.39	30.34	2.86	3.65
5	8.67	2.66	2.03	35.80	13.55	27.04		6.12
6	4.83	4.43	6.35	34.80	8.04	30.95		7.18
7		2.60	4.74	41.21	7.66	32.87	4.80	3.25
8	8.45	5.56	6.60	37.38	11.50	24.80		3.49
9		4.37	6.69	38.47	7.43	34.46	1.34	4.52
10		3.55	5.42	40.92	9.11	28.43	6.40	3.68
11	.26	5.79	8.12	38.91	10.84	28.29		4.03
12	3.18	4.43	5.84	36.98	8.29	31.02		6.55
13	2.33	5.14	8.04	37.64	12.68	25.22		4.82
14	2.25	4.31	6.18	37.68	11.49	30.30		4.52
15	5.29	3.43	8.97	35.28	11.82	27.52		5.13
16	8.01	5.91	15.23	32.90	16.72	14.55		2.47
17		.77	1.61	25.78	17.99	27.93	23.05	1.10
18		1.06	.68	46.86	6.30	32.49	6.18	4.01
19		.35	.51	69.41	3.25	15.05	10.42	.42
20	1.12	1.95	3.55	43.26	10.15	32.72		4.56
21		.06	.08	69.23	1.78	15.24	11.55	.47
22				70.67	3.02	11.15	13.57	.53
23		.65	.59	19.28	16.73	25.50	35.19	.95
24				82.89	.99		12.82	.53

TABLE 12a (cont'd)

SAMPLE	Q	OR	AB	AN	DI	HY	OL	IL
25		.30		69.16	2.24	14.64	11.62	.53
26	7.21	1.77	.76	63.65	2.30	22.04		1.03
27		.71	1.35	26.76	15.96	31.96	20.13	1.10
28		.59	.85	71.57	3.11	10.75	11.42	.53
29		.53		53.22	6.36	16.16	17.70	3.95
30		.53		49.40	3.82	15.07	25.43	3.36
31		1.00	1.35	26.89	17.52	29.38	20.66	1.20
32		.95	1.52	25.73	17.21	27.03	24.29	1.10
33		.41		69.38	2.07	13.55	12.48	.47
34		.65	.93	20.47	17.84	24.85	31.94	1.41
35	.13	1.06	3.98	24.37	22.86	31.01		14.40
36		.35		66.40	5.67	16.76	9.79	.53
37		.47	.25	69.48	3.19	14.68	10.62	.61
38		.53	.34	47.31	5.53	35.64	5.44	3.29
39				72.04	3.51	13.76	9.86	.38
40		1.30	1.10	11.86	17.76	18.24	17.64	31.15
41		.77	1.02	23.64	16.46	29.58	22.68	4.05
42		.71	.68	50.04	13.09	7.48	21.03	3.42
43		1.36	4.40	45.83	4.28	35.65	2.79	3.40
44		.83	1.86	48.26	5.12	32.63	7.92	3.08
45		.89	1.02	25.76	16.78	33.05	20.18	1.03
46		2.30	3.55	43.08	5.72	33.23	6.67	3.08
47		.65		48.52	4.53	24.14	16.42	3.13
48	.13	1.48	3.98	42.45	5.83	40.96		3.86

TABLE 13

14260,2 PYROXENE

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O_3	MnO	TOTAL	En	Fs	Wo	TOTAL
1	12.6	53.4	28.2	0.52	1.49	1.12	0.17	97.5	70	23	3	96
2	16.7	51.9	22.9	0.41	3.80	1.80	0.25	97.8	57	31	8	96
3	17.8	50.0	18.1	0.63	8.16	1.88	0.27	96.8	45	33	17	95
4	17.9	52.2	23.6	0.80	2.14	1.09	0.20	97.9	59	33	4	96
5	11.0	53.1	28.5	0.45	1.85	2.28	0.17	97.4	71	20	4	95

14260,2 PLAGIOCLASE

SAMPLE	FeO	SiO_2	MgO	CaO	Al_2O_3	TOTAL
1	0.11	43.4	0.19	19.1	35.4	98.8
2	0.13	46.2	0.13	16.3	33.5	98.4

TABLE 14

14318,6 CHONDRULE COMPOSITION

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O_3	MnO	K_2O	Na_2O	TOTAL	AN
"LUNAR CHONDRULES" - PLAGIOCLASE AND INTERSTITIAL GLASS-LIKE MATERIAL											
Chondrule #1 Av.2	0.95	44.5			17.6	33.1		lt .10	0.75	96.9	87
Glass in #1 (Not analyzed)											
Chondrule #2 Av.2	0.50	44.9			18.2	33.9		lt .10	0.63	98.1	90
Glass in #2	19.1	45.5	6.7	2.80	9.3	7.0				90.4	
	11.9	49.4	19.6	0.29	7.1	10.5				98.8	
Chondrule #3 Av.2	0.40	44.8			17.5	33.4		lt. 10	0.71	96.8	87
Glass in #3	10.1	52.1	6.2	0.61	7.6	9.3				85.9	
	15.3	51.0	8.5	0.24	14.3	22.3				111.6	
Chondrule #4 Av.2	0.53	45.1			17.7	33.5		lt. 10	0.73	97.6	88
Glass in #4	19.3	42.1	24.5	lt .10	2.9	4.7				93.5	
	12.6	43.8	3.8	1.39	14.5	11.6				87.7	
Chondrule #5 Av.2	0.66	47.1			17.9	33.4		lt. 10	0.85	99.9	89
Glass in #5	13.0	49.4	12.6	0.13	11.1	16.7				102.9	
	11.9	48.1	12.4	0.38	8.6	12.6				94.0	
Chondrule #6 Av.2	0.93	45.3			17.8	33.2		lt. 10	0.70	97.9	88
Glass in #6	14.4	48.9	12.4	0.36	10.2	12.8				99.1	
	13.0	50.5	13.4	lt .10	16.8	28.5				122.2	

TABLE 15

14318,6 BRECCIA GLASS (GLASS ONLY EXISTS IN HOST AND NOT IN RECRYSTALLIZED FRAGMENTS)

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O_3	MnO	K_2O	Na_2O	TOTAL
1	3.8	42.8	7.7	0.36	15.2	25.4	lt .10	0.20	0.11	95.6
2	8.8	48.2	7.8	0.90	12.0	18.6	0.14	0.52	0.55	97.5
3	9.0	49.4	7.8	0.96	12.8	17.4	0.18	0.31	0.25	98.1
4	4.8	46.7	5.5	0.24	14.9	23.9	0.10	0.24	lt .10	96.4
5	18.0	52.4	6.0	3.24	7.0	8.8	0.21	0.97	1.53	98.2
6	18.1	51.9	6.5	3.45	7.5	9.1	0.22	0.77	1.04	98.6
7	9.4	50.9	8.1	0.46	12.0	21.0	lt .10	0.48	0.61	103.0
8	9.4	49.3	8.7	1.07	11.1	16.6	lt .10	0.47	0.51	97.2
9	4.3	48.5	5.3	0.20	14.4	23.3	lt .10	0.21	0.41	96.6
10	16.4	47.0	8.2	2.23	10.7	13.4	0.22	0.48	0.52	99.2
11	2.2	44.6	4.9	0.10	16.4	27.5	lt .10	0.19	lt .10	95.9
12	10.0	49.7	11.0	1.77	9.7	14.8	0.11	0.76	0.74	98.6
13	8.1	49.3	10.6	0.80	10.9	17.8	0.11	0.40	0.54	98.6
14	9.2	48.7	7.7	0.96	11.7	18.0	0.12	0.53	0.68	97.6
15	8.8	48.2	7.9	1.00	12.0	18.0	0.11	0.54	0.63	97.2
16	6.4	48.7	6.1	0.42	13.8	21.5	0.15	0.21	0.41	97.7
17	8.8	48.0	7.9	0.84	11.9	18.3	0.15	0.58	0.58	97.0
18	9.4	48.5	8.2	0.94	12.0	18.4	0.17	0.49	0.54	98.6
19	8.8	49.2	7.7	0.94	12.0	17.9	lt .10	0.54	0.61	97.7
20	18.5	50.1	6.2	3.08	7.0	8.9	0.24	1.06	1.26	96.3
21	9.4	47.6	8.3	1.08	12.1	18.0	0.12	0.53	0.49	97.6
22	8.9	49.4	7.6	0.82	12.6	20.0	0.15	0.54	0.52	100.5
23	9.7	49.2	8.2	1.03	12.0	17.7	0.14	0.60	0.68	99.2
24	4.9	46.3	6.1	0.17	14.3	23.6	lt .10	0.20	lt .10	95.6
25	4.0	46.4	5.5	0.10	15.3	25.7	0.11	0.19	0.37	97.7
26	9.4	49.9	7.7	1.04	11.6	17.8	0.14	0.55	0.56	98.7
27	8.5	48.8	8.4	0.87	11.9	17.8	0.14	0.51	0.57	97.5
28	3.4	47.3	12.9	0.16	13.6	20.0	lt .10	0.20	lt .10	97.6
29	9.6	49.5	8.2	0.94	11.7	17.8	0.11	0.58	0.64	99.1
30	8.7	48.6	7.8	0.96	12.2	19.0	0.13	0.49	0.46	98.3
31	9.1	48.5	7.8	1.00	11.4	18.0	0.16	0.58	0.62	97.2
32	17.6	52.0	5.5	3.26	6.9	8.9	0.21	1.38	1.44	97.2
33	5.8	48.6	5.9	0.38	13.9	21.9	0.13	0.21	0.23	97.0
34	8.6	47.9	8.9	0.97	12.1	18.3	0.10	0.46	0.47	97.8
35	8.7	48.7	8.0	0.96	11.9	17.9	0.11	0.57	0.55	97.4
36	9.1	49.1	7.6	1.50	11.4	17.3	0.14	0.58	0.67	97.4

TABLE 15a

14318,6 GLASS NORM ANALYSES

SAMPLE	Q	OR	AB	AN	DI	HY	OL	IL
1		1.18	0.93	68.22	5.76	8.41	10.48	0.68
2	1.63	3.07	4.65	46.75	10.49	29.21		1.71
3	4.65	1.83	2.12	45.44	14.83	27.42		1.82
4	3.28	1.42	0.85	64.06	8.04	18.38		0.46
5	7.47	5.73	12.95	14.28	17.28	34.29		6.15
6	8.59	4.55	8.80	17.89	16.28	35.92		6.55
7	1.51	2.84	5.16	53.15	5.25	34.28		0.87
8	3.54	2.78	4.32	41.62	11.01	31.95		2.03
9	5.25	1.24	3.47	61.12	8.40	16.86		0.38
10		2.84	4.40	32.31	16.93	35.47	2.46	4.24
11	0.58	1.12	0.85	74.03	5.88	13.45		0.19
12	1.05	4.49	6.26	34.82	10.81	37.78		3.36
13	1.17	2.36	4.57	44.97	7.39	36.57		1.52
14	2.02	3.13	5.75	44.50	11.13	29.23		1.82
15	1.48	3.19	5.33	44.69	12.16	28.42		1.90
16	4.33	1.24	3.47	56.21	10.04	21.60		0.80
17	1.17	3.43	4.91	45.62	11.01	29.32		1.60
18	1.10	2.90	4.57	46.34	10.83	31.12		1.79

TABLE 15a (cont'd)

SAMPLE	Q	OR	AB	AN	DI	HY	OL	IL
19	2.90	3.19	5.16	44.51	12.32	27.92		1.79
20	5.27	6.26	10.66	15.50	16.26	36.54		5.85
21	0.44	3.13	4.15	45.35	12.04	30.46		2.05
22	1.59	3.19	4.40	50.65	9.75	29.40		1.56
23	1.02	3.55	5.75	43.47	13.19	30.31		1.96
24	2.80	1.18	0.85	63.36	6.17	21.09		0.32
25	0.90	1.12	3.13	67.91	6.49	17.93		0.19
26	3.74	3.43	4.74	44.34	10.86	29.64		1.98
27	2.08	3.01	4.82	44.51	11.88	29.54		1.65
28		1.18	0.85	53.53	11.05	25.36	5.48	0.30
29	1.89	3.43	5.42	43.99	11.55	31.03		1.79
30	2.25	2.90	3.89	48.33	9.99	29.15		1.82
31	2.20	3.43	5.25	44.62	9.80	29.97		1.90
32	7.34	8.16	12.19	13.75	17.35	32.23		6.19
33	5.55	1.24	1.95	58.11	8.88	20.61		0.72
34	0.59	2.72	3.98	46.47	11.07	31.14		1.84
35	2.35	3.37	4.65	44.69	11.75	28.76		1.82
36	3.66	3.43	5.67	42.49	11.54	27.76		2.85

TABLE 16

14318,6 PYROXENES (IN FRAGMENTS AND HOST)

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O_3	TOTAL	En	Fs	Wo	TOTAL
2	15.2	51.8	14.4	1.60	17.1	1.6	101.7	36	28	35	99
3	13.3	55.9	29.7	0.33	0.8	0.9	100.9	74	24	2	100
4	17.6	53.1	23.1	0.54	4.2	1.7	100.2	58	32	9	99
5	22.9	49.6	11.7	1.96	15.1	1.9	103.2	29	42	31	102
7	13.6	54.1	28.0	0.74	1.8	1.4	99.6	70	25	4	99
8	17.3	54.1	26.4	0.37	0.9	0.7	99.8	66	32	2	100
9	15.6	55.1	28.2	0.32	2.0	0.7	101.9	70	29	4	103
10	14.1	55.8	29.7	0.33	0.9	0.8	101.6	74	26	2	102
11	13.0	56.1	30.3	0.42	1.2	0.8	101.8	75	24	2	101
12	17.2	49.9	13.3	0.93	15.9	1.3	98.5	33	32	33	98
14	13.7	50.2	15.7	1.53	17.9	3.0	102.0	39	25	37	101
15	13.7	50.0	13.8	2.03	17.3	2.5	99.3	34	25	36	95
16	11.6	56.3	30.5	0.30	0.7	1.1	100.5	76	21	1	98

14318,6 OLIVINES (IN FRAGMENTS AND HOSTS)

SAMPLE	FeO	SiO_2	MgO	TOTAL	FA
2	28.9	37.3	34.7	100.9	41
3	29.6	37.3	34.1	101.0	42
4	30.6	36.8	33.8	101.2	43
5	30.2	37.0	33.6	100.8	43
6	30.3	36.8	33.5	100.6	43
7	29.9	36.9	34.0	100.8	42
8	30.3	37.0	33.5	100.8	43
9	30.4	37.2	33.6	101.2	43
10	32.3	36.6	32.3	101.2	46
11	30.6	36.6	33.5	100.7	43
12	25.6	37.0	36.4	99.0	36
13	10.7	40.3	48.7	99.7	15
14	29.7	37.4	33.7	100.8	42
15	20.3	38.6	40.9	99.8	29

TABLE 16 (cont'd)

SAMPLE	FeO	SiO_2	MgO	TOTAL	FA
16	28.9	37.1	33.5	99.5	41
17	17.1	38.4	42.4	97.9	24
18	27.6	37.5	35.1	100.2	39
19	23.1	37.5	37.9	98.5	33
20	30.1	36.7	32.9	99.7	43
21	29.1	36.5	33.8	99.4	41
22	29.2	37.2	33.9	100.3	41
23	30.9	36.4	31.5	98.8	44
24	30.3	35.9	31.8	98.0	43

14318,6 OTHER PLAGIOCLASE GRAINS (IN FRAGMENTS AND HOST)

SAMPLE	FeO	SiO_2	CaO	Al_2O_3	K_2O	Na_2O	TOTAL	AN
2	0.15	55.5	8.4	25.6	2.30	4.02	96.0	42
3	0.11	44.0	18.2	35.1	0.15	0.91	98.5	90
4	0.44	43.7	17.3	34.0	0.11	0.60	96.2	86
5	0.17	44.0	18.7	35.2	lt .10	0.60	98.7	93
6	0.52	44.7	16.1	32.7	0.18	0.97	95.2	83
7	0.28	46.0	17.4	34.1	0.17	1.34	99.3	86
8	0.62	48.4	14.8	31.2	0.52	2.73	98.3	73
9	0.19	47.7	16.3	33.0	0.36	1.99	99.5	81
10	0.19	45.2	17.3	34.3	0.17	1.24	98.4	86
11	0.23	44.2	19.2	35.7	lt .10	0.45	99.8	95
12	0.23	51.6	13.3	30.2	0.66	3.30	99.3	66
13	0.19	45.5	18.8	35.2	lt .10	0.58	100.3	93
14	0.15	46.6	16.8	33.7	0.14	1.40	98.8	83
15	0.17	47.6	16.0	32.0	0.22	1.90	97.9	79
16	0.49	49.2	13.4	30.1	0.42	2.73	96.3	67
17	0.13	48.7	15.1	31.9	0.35	2.27	98.4	75

TABLE 17

14321,27 OLIVINE AND PYROXENE IN THIS ESSENTIALLY GLASS-FREE BRECCIA

SAMPLE	FeO	SiO_2	MgO	TOTAL
OLIVINE				
2 Margin	20.4	38.7	39.6	98.7
3 Center	16.4	39.9	43.1	99.4
4 Margin	19.5	39.2	40.5	99.2
5 Center	12.2	40.4	46.5	99.1
6 Margin	22.0	38.7	36.6	97.3
7 Center	10.6	40.3	47.9	98.8
8 Margin	18.7	39.0	41.5	99.2
9 Center	19.4	39.5	40.5	99.4
10 Margin	20.0	38.2	40.6	98.8
11 Center	13.7	40.8	45.4	99.9
12 Margin	20.7	38.7	39.3	98.7
13 Center	21.6	38.0	39.7	99.3
14 Margin	25.1	38.2	36.2	99.5
15 Center	22.5	38.8	38.6	99.9
16 Margin	23.2	38.3	37.4	98.9
17 Center	12.1	40.0	47.1	99.2
18 Margin	17.1	39.7	42.8	99.6
19 Center	15.6	38.8	45.2	99.6
20 Margin	20.4	39.0	41.3	100.7

TABLE 17 (cont'd)

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O_3	TOTAL	En	Fs	Wo	TOTAL
PYROXENE											
6 Center	7.8	56.6	32.9	0.46	0.74	1.14	99.6	82	14	2	98
7 Margin	8.1	55.1	32.7	0.43	0.68	1.14	98.2	81	15	1	97
8 Center	8.1	54.8	32.7	0.53	0.79	0.98	97.9	81	15	2	98
9 Margin	8.3	55.0	32.7	0.41	0.99	1.01	98.4	81	15	2	98
11	24.8	50.8	18.5	0.36	3.70	0.74	98.9	46	46	8	100
12	20.6	51.6	24.2	0.32	1.26	0.61	98.6	60	38	3	101

TABLE 18

14321,100A

SAMPLE	FeO	SiO_2	MgO	TiC_2	CaO	Al_2O_3	MnO	K_2O	Na_2O	BaO	TOTAL
2 RECRYSTALLIZED MATRIX FRAGMENTS											
Myrmekitic Intergrowth											
Feldsp.	0.32	80.2	0.01	0.23	0.80	12.6	0.02	4.57	0.29		99.0
Quartz	0.13	97.0	0.07	0.25	0.50	2.03	0.02	0.57	0.10		100.7
Feldsp.	0.77	73.3	0.41	0.14	0.27	13.2	0.06	9.91	0.10	4.8	103.0
2 RECRYSTALLIZED BASALTIC FRAGMENTS											
Plag.	0.74	50.9	0.14	0.21	14.5	29.1	0.02	0.67	2.31		98.6
Pyrox.	12.3	49.3	16.1	2.69	15.0	4.5	0.23	0.23	0.07		100.4
Plag.	0.46	45.1	0.04	0.04	18.5	34.1	0.41	0.26	0.11		99.1
Pyrox.	23.4	49.5	11.7	1.14	13.8	1.95	0.33	0.19	0.09		102.1
Pyrox.	17.7	49.8	18.7	1.17	7.8	4.8	0.37	0.20	0.04		100.6
2 LARGE PLAGIOCLASE CLASTS											
Plag. unzoned	0.13	50.4	0.00	0.05	15.0	32.0	0.02	0.23	2.57		100.4
Plag. "	0.13	50.0	0.00	0.04	15.4	32.2	0.00	0.29	2.67		100.7
Plag. Center	0.18	49.6	0.00	0.05	15.0	31.2	0.02	0.16	2.32		98.5
Plag. Margin	0.22	53.6	0.00	0.03	12.8	29.1	0.02	0.92	3.42		100.1
Plag. Margin	0.18	53.1	0.00	0.05	12.0	29.2	0.04	1.06	3.58		99.2

TABLE 18 (cont'd)

14321,100A

SAMPLE	FeO	SiO_2	MgO	TiO_2	CaO	Al_2O_3	MnO	K_2O	Na_2O	BaO	TOTAL
2 LARGE HYPERSTHENE FRAGMENTS											
Pyrox. Margin	14.3	53.0	26.9	0.85	2.1	2.02	0.21	0.09	0.03		99.5
Pyrox. Center	20.3	53.2	22.7	0.42	4.5	0.92	0.32	0.20	0.09		102.6
Pyrox. Center	16.4	54.0	25.0	0.25	4.8	0.58	0.30	0.25	0.06		101.6
Pyrox. Margin	15.3	54.8	27.2	0.32	1.9	1.40	0.21	0.19	0.04		101.4
Pyrox. unzoned	10.1	56.0	32.7	0.03	0.73	0.86	0.18	0.14	0.02		100.8
Pyrox. "	9.9	55.8	32.5	0.30	0.84	0.95	0.19	0.15	0.01		100.6
1 LARGE MEDIUM-GRAINED UNDEFORMED BASALTIC FRAGMENT											
Plag.	0.43	46.9	0.02	0.03	17.8	34.1	0.05	0.23	1.04		100.7
Plag.	0.37	46.7	0.04	0.02	18.4	33.7	0.03	0.22	1.03		100.5
Pyrox.	29.4	48.2	8.0	1.06	11.9	1.5	0.40	0.22	0.09		100.8
Pyrox.	30.3	47.8	8.1	0.93	9.5	1.3	0.45	0.21	0.08		98.7

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LUNAR CHONDRULES

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Many of the impact generated spherules from the lunar surface show a manifest resemblance to various types of meteoritic chondrules. Quenched olivine crystals in such lunar chondrules also frequently have a constant Fe/Mg ratio as do those of chondrules in ordinary ("equilibrated") chondrites. This provides direct evidence for one of the more plausible processes of chondrule formation, i.e., impact melting. Among the great variety of breccias from Mare Procellarum (Apollo 12) and especially from the Fra Mauro "highland" site (Apollo 14) there are many which closely resemble chondrites of the LL-group (especially so-called LL 5 and 6) in texture and structure and both types of rocks may be interpreted as impact-ignimbrites. Also in both cases repetitious processes of fragmentation and agglomeration-welding are indicated. The differences in abundances of chondrules and chondrule types between the lunar breccias and the most common chondrites are interpreted as due to gross mechanical and chemical differences in the respective parent materials.

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IMPACT ROCKS - LUNAR, METEORITIC and TERRESTRIAL

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Abstract:

The structural resemblance between 1) some impact-generated lunar spherules and chondrules and 2) between lunar "micro-breccias", brecciated chondrites and terrestrial impactites is described. While the few surviving terrestrial impactites are the result of single impacts, many chondrites and lunar breccias show evidence of repetitious events of break-up and accumulation-welding. It may be concluded that most, if not all, chondrites, as well as the lunar breccias, are impact-generated rocks. It is possible that impacts were a major rock-forming process on many bodies in the early solar system because: 1) Lunar micro-breccias (impact-ignimbrites) are abundant on the Moon, especially on the Apollo 14 and 15 sites, 2) Impacts were more frequent in the early history of the Moon (and consequently on the Earth and probably on other planets also), 3) Chondrites (impact-ignimbrites) are predominant among meteorite falls, and they are all $\sim$ 4.6 b.y. old and 4) Impacts can provide substantial amounts of localized energy compared to present-day terrestrial volcanism.

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